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ABSTRACT

This document reports on a study of two approaches to an analytical chemistry course: (1) a structured active learning approach; and (2) a step-by-step lecture style problem solving approach. The purpose of the study was to assess and compare the outcomes of these approaches. The data consisted of open-ended interviews with students, open-ended student survey questions, Likert scale student survey items, and faculty interviews. The study concludes that a number of positive effects of structured active learning are documented, and although it is possible to assert that a comparison group does not report the kinds of learning outcomes that the structured active learning group reports, further study is needed to be sure that the findings are reliable. (DDR)

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ED 412 097

Formative Feedback Report #3

End of Semester Interviews and Preliminary Findings of the Faculty Assessor Project

CHEM 110, SPRING 1995
UW-Madison

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prepared
for

the Leadership Group of the
"Establishing New Traditions: Revitalizing the Curriculum" grant awarded to the
Chemistry Department, College of Letters and Science

and

Leon Shohet and Denice Denton
PIs of the "Diversity and Cultural Change: Manufacturing Engineering Education for the Future"
grant awarded to the
Engineering Research Center for Plasma-Aided Manufacturing, College of Engineering

by
The LEAD Center

LEAD Center Project Team:
Susan Millar, Judy Pasch, Debra Penberthy, Steve Kosciuk

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1402 University Avenue, Rm 435, Madison, WI 53706
608 265-5920 • fax: 608 265-5923 • email: lead@engr.wisc.edu

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Notes

Executive Summary[1]

The *Chemistry 110 Formative Feedback*[2] *Report # 3* (FF#3) on which this executive summary is based is a work-in-progress. A massive set of data was collected and data collection was completed only in mid-June, 1995. It is not feasible in the short time elapsed since data collection was complete to report on all the information collected, or to produce anything but a very preliminary analysis.[3] Significant refinements of the analysis presented here will appear in subsequent reports and research articles. Please note that *no* analysis of the faculty assessor interview material have been completed, and only a few sections of the faculty assessor and student surveys have been included.

Readers of the FF#3 report may wish to refer to material presented in Formative Feedback Reports #1 (March 1995) and #2 (April 1995) for further information. This executive summary is written to stand on its own, but is based almost entirely on the findings presented in FF#3.

This work is funded by both the ARPA-TRP "Diversity and Cultural Change: Manufacturing Engineering Education for the Future" (MEEF) grant (#ECD-8721545) awarded to the Engineering Research Center for Plasma-Aided Manufacturing, College of Engineering, and the "New Traditions: Revitalizing the Curriculum" (NT) grant (#DUE-9455928) awarded to the NT Leadership Group based in the Chemistry Department, College of Letters and Science. Both grants are administered by the National Science Foundation.

The findings presented here are based on both qualitative and quantitative information. The qualitative findings are drawn from case studies of the two lecture sections of Chemistry 110 taught in spring 1995. Professor Wright's "structured active learning" approach is the focus of one, and Professor Wood's "responsive lecturing" approach is the focus of the other case study. The two methods are described in detail below. The quantitative findings are drawn from the university student database, student surveys, and rankings of 180 of the Chemistry 110 students that 25 faculty assessors from outside the Chemistry Department generated.

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[1] The Chem 110 LEAD research team extends special thanks to Lyman Lyons and Baine Alexander (LEAD Center) for their support in helping produce this report.

[2] Evaluation is "formative" when applied researchers give program reformers feedback while the program/activity is being planned, piloted, and scaled up, and with the intention of improving the program/activity while it is under development.

[3] Detailed information about the data sources on which FF#3 is based is presented in the full report.

Background on Chemistry 110, Spring 1995

Chemistry 110, a course in analytical chemistry, attracts about 200 students each spring. It is the second semester of the 109-110 introductory chemistry course sequence intended for science and engineering majors. The Chem 109-110 course sequence provides in two semesters approximately the same material presented in the three Chem 103, 104 and 221 course sequence. Chem 109 is taught in two lecture sections, each of which enrolls about 200 students. About half of the students who enroll in Chem 109 in the fall take Chem 110 in the next semester.

Formal class time is structured into three major components: fifty-minute lectures presented three times a week by a professor; two four-hour labs twice a week, facilitated by TAs; and a one-hour discussion section conducted by a TA. Each TA works with the same group of students for both lab and discussion section.

In spring 1995, the course enrolled a section of 105 students taught by John Wright, and a section of 85 students taught by Claude Woods. Survey data show that 67 percent of the Wright students had intentionally registered in Wright's section (lecture scheduled at 8:55 a.m.), and that 20 percent of the Woods students had intentionally registered in Woods' section (lecture scheduled at 11:00 a.m.). The two lecture sections showed similar distributions when the students in each were ordered according to total points earned in Chem 109. Woods students were randomly assigned to five different lab/discussion sections. Wright grouped his students into six lab/discussion sections roughly according to intended major.

All but 10 of the 188 students who enrolled in Chem 110 were first-year students. Course enrollment by college was 16 percent in CALS, 32 percent in COE, and 52 percent in L&S. Of the pre-engineering students, 65 percent were intending to major in chemical engineering and all but one of the others had not yet registered an intended major. Seventy-five percent of the students overall had not yet registered an intended major. Women students constituted 37 percent of the total. Minority enrollment, except for Asian Americans (17 percent), was negligible (3 of the 188 students who enrolled). Three students dropped the course.

Both Claude Woods and John Wright have taught undergraduate and graduate courses at UW-Madison for many years and earned high regard from their colleagues and students for excellence in teaching. Claude Woods, a physical chemist, has taught Chem 110 six times, most recently (prior to spring 1995) in spring 1989. John Wright, an analytical chemist, has taught Chem 110 every year since he began at UW-Madison in 1972. The TAs' college-level teaching experience ranged from one semester (two TAs) up to eight years (one TA).

Professor Wright's "Structured Active Learning" Method

In the spring of 1992, Professor Wright changed both his goals and teaching strategies for Chem 110. Prior to beginning his spring 1992 course, he had been assigning students independent projects. Through conversations with his students he realized they enjoyed these projects but did not have the depth of understanding needed to apply their chemistry knowledge to new contexts. This led him to formulate a new goal: the course should foster the problem-solving skills and creativity needed to solve difficult and realistic problems. He developed an overall strategy for achieving these goals, which is to force students to assume more responsibility for learning the course material by giving them "opportunities to creatively explore projects that have defined goals, and in the process to improve their skills." He introduced a carefully planned set of "structured active learning" strategies designed to achieve his goals. These include:

- an absolute grading scale to replace the "curve"
- student lab groups that complete three open-ended laboratory projects (during the first 6 weeks of the semester, students complete standard lab experiments)
- student lab groups that read and analyze research papers
- interactive techniques in the lecture, including think-pair-share, collaborative problem solving, concept tests, and list generation exercises
- difficult cooperative take-home exams
- spreadsheet programs for homework and laboratory problems
- a student board of directors that advises on all aspects of the course

Professor Woods' "Responsive Lecturing" Method
Having taught Chem 110 six times and observing the way students respond to different aspects of the course, Professor Woods developed a "responsive lecturing" approach. His goals for the course are "to provide students a total immersion experience in chemistry...and to give them some idea of how professional chemists attack and think about problems." Main features of his responsive lecturing approach include:

- traditional lecturing approach and the standard Chem 110 laboratories
- major emphasis on homework problems
- spreadsheet programs in homework assignments
- modeling by example what professional chemists think and do
- informal interaction with students through regular visits to lab sections
- active lines of communication with TAs to remain attuned to the students' level of knowledge

Background on the Chem 110 Evaluation/Assessment Project

Comprehensive plans for formative evaluation of both the MEEF and NT projects were developed during the grant proposal development process. The MEEF grant proposed including an evaluation of Chem 110 during 1994-95, as did the NT grant. In December 1994, shortly after the NSF announced that the NT grant would be awarded to UW-Madison, Professor Wright began working with the LEAD Center to design an evaluation/assessment project. He wanted the LEAD Center to obtain third-party evidence about the effects of his approach on student learning. In addition, he sought to ensure that the evidence collected would be meaningful to his Chemistry Department colleagues. Therefore, as John Wright wrote in a recent letter,

> I assembled four representative Chemistry Department faculty who are known for their wisdom and critical thinking and asked them what would be required for a course evaluation to be credible. In particular, I asked what they would need to be convinced to try it. After much discussion, they concluded that they would require outside faculty oral examinations of all students in the class on their ability to perform critical thinking and problem solving.

Professor Wright, meanwhile, had asked Professor Woods if he would agree to include his spring 1995 Chem 110 section as a comparison group so that a quasi-experimental research design could be used. He anticipated that the in-coming characteristics of the two Chem 110 student groups would be very similar. This would minimize factors other than the teaching methods that might affect student performance and maximize the opportunity to compare thinking skills between closely matched groups of students. Professor Woods, confident in his own method and intrigued by the prospect of the study, agreed. Professor Wright and the LEAD Center then drafted an evaluation/assessment proposal. The proposal was finalized with input from Professor Woods.[4] The basic ideas shaping the assessment portion of the project were formulated by Wright. The design was modified with guidance from Professor Bruce Wampold (Counseling Psychology).[5]

Data collection methods used for the *evaluation* component included two structured open-ended interviews with 39 generally representative students (20 and 19 from the two sections, respectively), all 11 TAs, and the two faculty members, classroom observations, an open-ended student survey (return rate: 100%), and one structured open-ended interview with each of the 25 faculty assessors. The quantitative data drawn from the university student database and student surveys are used in both the evaluation and assessment components of the study.

Data collection methods used for the *assessment* component included a "competency" assessment of the Chemistry 110 students by 25 faculty assessors in departments other than the Chemistry Department. Students in each of the two lectures were divided into octiles based on their gradepoint percentile in Chem 109. Approximately 24 students in each octile were interviewed by one of three professors assigned to an octile. Each assessor met one-on-one for half-hour interviews with approximately one-third of the students in the assigned octile, with proportionate representation from the two Chem 110 lectures in each assessor's group. Professors were given no information about the students' lecture section or octile level. Both students and faculty were requested to keep this information confidential. The task assigned each professor, to "assess the competence" of each student, was intentionally very open-ended. Professors Wright and Woods provided brief syllabi of their courses and some material from the textbook, but provided no guidance on how to conduct the oral examinations or what criteria to use to rank the students. The assessors each developed their own criteria, completed an evaluation sheet on each student, ranked the students in their group both relatively and on their own absolute scale, and described in writing the criteria used to rank students.

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[4] Copies of the *Assessment and Evaluation of Chemistry 110* proposal may be obtained by contacting the LEAD Center.

[5] A detailed description of Chem 110 Assessment Project design plus the evaluation forms and survey questionnaires completed by both faculty assessors and students appear as appendices to Formative Feedback # 3.

Research Questions

We list here the research questions investigated by the evaluation/assessment project, as articulated in the evaluation/assessment proposal.

1. To minimize factors other than the teaching methods that might affect student performance, it is important that the two student groups in the study have similar characteristics. Are the incoming characteristics of the students in the two Chem 110 lecture groups sufficiently similar?

2. To help distinguish "instructor" effects from "method" effects, it is important to determine whether each lecturer effectively implemented his method of teaching. Did each faculty member implement his method at the "high end" on a performance scale?

3. If the answer to Question 1 is yes, does qualitative information obtained in student, TA, and faculty interviews and through classroom observations show patterns in student learning experiences that are distinct for each method? In other words, are "method effects" apparent from the qualitative data?

4. If the answer to Question 2 is yes, what features distinguish each method? In particular, how do students experience the atmosphere in each class with respect to:

    degree of students' sense of individual accomplishment
    efficiency in using students' time
    degree of student cooperation and competition
    degree of passive and active learning
    level of individual accountability
    where work groups are used, level of group accountability and interdependence
    level of enjoyment
    level of motivation
    sense of community

5. Do the results of the oral assessments conducted by faculty assessors show measurable differences between the two methods? If so, what criteria did faculty assessors use to gauge student learning? What can be learned from the entire process in which the faculty assessors engaged?

Preliminary answers to these questions are provided in the remainder of this Summary. The research questions do not directly address the experiences of the Chem 110 TAs, and the preliminary answers rarely draw on the findings (presented in FF#2) from the TA interviews.

Research Question 1.

> ***To minimize factors other than the teaching methods that might affect student performance, it is important that the two student groups in the study have similar characteristics. Are the incoming characteristics of the students in the two Chem 110 lecture groups sufficiently similar?***

As noted above, the students in the two lecture sections showed similar distributions when the students in each were ordered according to total points earned in Chem 109. Thus, with respect to academic performance characteristics, the groups were comparable. Previously noted student survey data reveals that 67 percent of the Wright students and 20 percent of the Woods students intentionally registered in their respective lecture sections. This suggests, considering each group as a whole, student learning styles and motivation levels may have been significantly different. As no learning style or motivation inventories were administered when the students enrolled in the course, it is not possible to assess if these were significant factors. However, cross-tabulations by student self-selection group and faculty assessor rank (see Question 5, below) indicate self-selection is independent of rank. In fact, in Wright's class, the non-self-selected students received proportionately higher ranks than the students who self-selected into this section, although not to a sufficiently dramatic degree to negate the hypothesis of independence ($p = .13$). This means that students who did not intentionally choose this section performed somewhat better in faculty assessor ranks than those who self-selected into Wright's class. The p-value for independence of self-selection status and faculty assessor rank for Woods' section was high, strongly suggesting that these two factors were independent for this section. In a similar manner, self-selection was independent of: gender, Chem 109 lecture section, Chem 109 octile groupings, and Chem 110 final grades.

Research Question 2

> ***To help distinguish "instructor" effects from "method" effects, it is important to determine whether each lecturer effectively implemented his method of teaching. Did each faculty member implement his method at the "high end" on a performance scale?***

We conclude that each faculty member implemented his chosen method at an exemplary level. Classroom observation data (see analysis in Formative Feedback #2) and student interview data indicate student attendance, attentiveness, and participation levels in each lecture section were very high in comparison to typical lectures with similar enrollment. While a few of the 39 students interviewed expressed some dissatisfaction with specific features of their lecturer's approach, all gave their lecturer high marks for the skill and care with which the lectures and other course components associated with each method were implemented.

Both qualitative and quantitative data suggest that instructor effects may be present at the lab (TA) section level. However, information about these effects was not systematically gathered.

Research Question 3

> ***If the answer to Question 1 is yes, does qualitative information obtained in student, TA, and faculty interviews and through classroom observations present patterns in student learning experiences that are distinct for each method? In other words, are "method effects" apparent from the qualitative data?***

The case studies of the two Chem 110 lecture sections indicate each is characterized by distinct patterns in student learning experiences. We are confident that method effects are present and have important consequences for student learning.

Key patterns emerging for the Wright students include:

- Many students developed productive connections between course activities (lecture, lab, and other course components) and the course concepts developed because of the research oriented, structured group activity. Students emphasized that course components strongly reinforced each other and enhanced learning.

- The course structure fostered an awareness of the complexity and difficulty of real-life research. Students felt that to successfully understand professional-level research articles, to complete exceptionally difficult take-home exams, and to solve very difficult open-ended lab problems, they had to work together and develop cooperative group strategies.

- The effectiveness of the assigned work groups varied. The highly functional groups experienced cooperative and mutually supportive interactions characterized by equal contributions and commitment to the group. These groups strove toward collective comprehension of the concepts. Dysfunctional groups experienced unequal contributions and commitment and aimed for expediency rather than common understanding of the material. Overall, students felt that the atmosphere of the class was supportive and non-competitive.

- Student responses were bimodal. *Students who flourished* (15 of the 19 interviewed) upon being presented with the "structured active learning" approach regularly attended lecture and lab, participated in both assigned and informal study groups characterized by genuine interdependence, enjoyed the challenge of solving open-ended problems, and acquired greater self-reliance. Most of the *students who did not flourish* (4 of the 19 interviewed) tended to skip lectures and labs and rely on classmates' notes, often worked independently, favored the cookbook labs and preferred doing homework alone with the book.

Key patterns that emerged for the Woods students include:

- Both a strong sense of accomplishment in having mastered Wood's approach to analytic chemistry and a high regard for the professor were expressed by many students. Students tended to focus on how much they appreciated the professor, with his brilliance as a lecturer, his role as the creator of the methods used in the class, and his patience and care in responding to student questions drawing many comments. A few students viewed him as a model of the kind of scientist they might wish to be.

- The course was experienced as a thorough "step-by-step" approach to problem-solving, with a focus on mathematical modeling. Many students emphasized that success on exams depended on hearing and understanding every lecture and practicing the professor's methodical approach by completing all the homework problems. Students also frequently remarked that they had to rely on the professor as practically their sole source of information and understanding because his approach to analytical chemistry was not used by the assigned textbook, was not well-understood by some of the TAs, and was not presented in course notes. Many students were confused and frustrated because a syllabus and clear grading procedures were not provided.

- Student-student interactions varied for different people due to the informal nature of group formation. Many students formed voluntary work groups that greatly assisted them in learning chemistry. In addition to small group interactions, classwide cooperation characterized student-student interactions during the "unknown" labs at the end of the course. At the same time, some students reported interacting with a limited number of students nearby in lab and in lecture. A few did not form work groups, either by choice or because they were left out of (in students' terms) "cliques."

- Changes in course features were evident at the end of the semester. Students noted an increase in the frequency and importance of informal group interactions, found that a closer relationship between lab and lecture emerged, and explained that there was an increased use of the textbook, in part, because the professor assigned readings. All of these changes were somewhat linked to independent "unknown" labs at the end of the semester, which students found challenging and enjoyable. Students also noted that the professor presented material more rapidly, assumed more previous knowledge than earlier in the semester, and began skipping steps in his explanations. Some students reacted positively to these challenges and others reported feeling somewhat lost.

Research Question 4

If the answer to Question 2 is yes, what features distinguish each method? In particular, how do students experience the atmosphere in each class with respect to:

degree of students' sense of individual accomplishment
efficiency in using students' time
degree of student cooperation and competition
degree of passive and active learning
level of individual accountability
where work groups are used, level of group accountability and interdependence
level of enjoyment
level of motivation
sense of community

Features that distinguish the experiences of students in Wright's course:

Employing interactive techniques in lecture and collaborative problem solving methods in discussion section and lab heightened students' sense of individual accomplishment. These structured active learning techniques provided students ample opportunity to talk chemistry with fellow students, TAs, and Professor Wright. However, students did not always exhibit efficiency in their use of time. TAs and students reported that some groups needed to learn how to establish and realize group priorities and deadlines.

In general, Wright students and TAs reported a high level of student cooperation and low level of competition in this class. From the beginning of the class, students were required to work in groups and given exceptionally challenging assignments, such as deciphering sophisticated research articles, completing challenging and time-consuming take home exams and problem sets, and engaging in three independent research projects in lab, the results of which they reported in group oral exams with the professor. Students almost uniformly commented that they found they had to rely on one another's different ideas, knowledge and abilities in order to complete these assignments. The combination of exceptionally challenging assignments and structured active learning strategies resulted in notably high student engagement with the course material.

At the same time, some Wright students expressed concern about the level of individual accountability in the group learning environment. Although many students felt an obligation to their group and indicated that every member of the group contributed mutually and strove to fully understand the concepts, several students spoke of group members who could not be counted on to carry their own weight or who were assigned trivial tasks in the division of labor due to a lack of trust and perceived accountability. Due to this disparity in contributions, students reported that the grades on group projects often reflected the understanding level of those who contributed most. Thus, some students' grades were higher than they would have been had they been tested individually. Individual exam grades more accurately reflected the rang of understanding levels.

Most of Wright's students demonstrated, both in regular class attendance and hours spent on take home exams and homework, a high level of motivation. Many students stated that the amount of time spent on the course was extremely high. In fact, the major complaint heard from students pertained to the amount of time spent in lecture, lab, discussion section, take home exams and homework assignments. This complaint was brought to Wright's attention by the appointed Student Board of Directors. Students reported that the professor responded by making the workload to a more manageable level.

Overall, students expressed a high level of satisfaction with and a strong sense of accomplishment in the course.

Features that distinguish the experiences of students in Woods course:

Woods employed a problem-solving approach to Chem 110 that involved a step-by-step lecture style. He was always patient and careful in providing explanations to students, and regularly visited all the labs. Although he held no office hours, he was always available after class and other times at the request of the students. Many students stated that lecture, homework and exams were closely connected, providing students a step-by-step process for learning the approach to analytical chemistry that Woods had developed. In particular, homework problems were carefully designed to give students the opportunity to practice these methods. Students reported that the exams consisted of problems very similar to the homework and that success depended on doing the homework problems. One effect of this step-by-step lecture-homework-exam structure that students experienced was difficulty when exam problems started in the middle of the sequence of steps.

Students voiced a concern about lack of alternative learning resources: Woods taught students a method he developed and this method was not supplemented in the course text, not presented in course handouts, and not well-understood ahead of time by all the TAs. Two effects of this arrangement were noted. Students conveyed a desire for sources of knowledge other than the instructor, and students were strongly motivated to attend class regularly and pay close attention.

In general, students felt there was little competition among students. Students felt that each student strove to perform as well as he or she could. However, most students expressed concern about their grades. A few also seemed confused about the grading system and the unspecified application of the "curve."

One source of frustration reported by students was the disjunction between lab and lecture. Most students perceived this, but many also believed it was unavoidable. Although most students stated that they learned meticulous lab technique, some dissatisfaction with the low level intellectual challenge of "cookbook" labs was expressed; students felt they could complete the labs without really understanding what they were doing. However, students reported almost universally positive reactions to the final independent project, which required them to determine the composition of an "unknown" substance. In response to this lab, some students said they felt like real scientists.

As noted above, the character of student-student interactions was varied due to the informal voluntary nature of the group formation process. Many students reported being members of close informal work groups and noted that the level of interaction with labmates and students sitting nearby in lecture increased as the semester proceeded.

A few students reported that their experience in the course gave them a very high sense of individual accomplishment and an appreciation for science and for the exactitude of scientific experimentation. A few discussed how the course gave them an increased interest in chemistry. For some, a major outcome of this course was the close friendships they formed. Once having adjusted to Woods' style of teaching, many students expressed a high regard for Woods and their overall experience in Chem 110.

Research Question 5

> ***Do the results of the oral assessments conducted by faculty assessors show measurable differences between the two methods? If so, what criteria did the faculty assessors use to gauge student learning? What can be learned from the entire process in which the faculty assessors engaged?***

The ranks faculty assessors assigned to the Chem 110 students were not distributed homogeneously between the two different lectures. In fact, students in Wright's lecture received a noticeably larger proportion of the high ranks. Since it might be expected that faculty assessment criteria would have a significant effect on the assignment of ranks, an attempt was made to explain this disparity by including faculty assessor criteria effects in our analysis of the assigned ranks. Our investigation showed that faculty assessors who placed a great emphasis on what we termed a student's "meta-awareness" of his/her problem solving techniques noticeably favored Wright students. Nonetheless, we cannot rule out the idea that other factors may account for this disparity as well or better than this factor. (See Section 9, "Preliminary Quantitative Findings," of FF#3 for a statistical treatment of these data.)

At this point our analysis of the criteria that the faculty assessors used to gauge student learning is too preliminary to present in any detail. A complete analysis of the faculty assessor interview transcripts will allow a more careful analysis of these quantitative data, and will be the subject of forthcoming reports and articles. These forthcoming studies also will investigate what can be learned from the entire process in which the faculty assessors engaged.

Introduction to Formative Feedback #3

This *Chemistry 110 Formative Feedback Report # 3* (FF#3) is a work-in-progress. A massive set of data was collected and data collection was completed only in mid-June, 1995. It is not feasible in the short time elapsed since data collection was completed to report on all the information collected, or to produce anything but a very preliminary analysis. Significant refinements of the analysis presented here will appear in subsequent reports and research articles. Please note that *no* analysis of the faculty assessor interview material has been completed and only portions of the faculty assessor and student surveys have been included.

This report presents findings based on both qualitative and quantitative information. The qualitative material is structured into a case study of Professor Wright's "structured active learning" approach to Chem 110, and a case study of Professor Wood's "responsive lecturing" approach. Each case study includes three sections: a presentation of the goals articulated by each faculty member for his class, key themes emerging from the student interviews, and key themes from the TA interviews (Sections 3 through 8). An analysis of the quantitative data appears in Section 9. Each of the long sections (4, 5, 7, 8, and 9) begins with a separate table of contents to help guide the reader.

It is important to note that this report's format and content are shaped by its purpose and methods. The primary purpose is to provide the Chem 110 faculty and the MEEF and NT clients formative evaluation information. Evaluation is formative when it is provided to faculty reformers as feedback while their program is being implemented. In this case, although the spring 1995 Chem 110 course has ended, the faculty and other interested parties seek analysis information on a short time-frame to facilitate planning processes that may effect both future iterations of Chem 110 and other courses. Because the analysis of the qualitative material is a "first pass" through the data, the qualitative sections are long, and analysis is apparent largely in the selection and organization of material drawn directly from the student, TA, and faculty interviews.

Qualitative and quantitative research methods differ not only with respect to data collection but with respect to analysis. Individual and focus group interviews and classroom observations allow the researchers to "get inside of" the experiences of these diverse participants. Data collection methods are as open-ended and subject-responsive as feasible to ensure that the experiences of the study subjects, not the researchers, are reported. Likewise, analysis processes are fundamentally inductive to ensure that the subjects' experiences shape the findings. In practice, this means that the researchers make every effort to at least temporarily suspend the ideas that structured their interview protocols and classroom observations. Analysis begins by reading transcripts with an eye to what is most important to the participants. The primary analytical categories that emerge as the researchers process the transcripts are apparent in each case study's table of contents. In contrast to survey methods, these methods do not yield precise, quantitative assessments of the proportion of participants holding pre-specified opinions. However, these methods provide extraordinarily rich information expressing the complexity of the lived experiences of the study subjects.

For general background information about the Chem 110 course and the evaluation and assessment study, please consult the Executive Summary (Section 1). Likewise, a synthesis of the material appearing in the case study and quantitative sections of the full report appears in the Executive Summary.

Data collected since formative feedback #2:

This report is based on the types of data presented below, unless noted otherwise.

1. Interviews

Structured open-ended interviews lasting approximately 1 hour were conducted with the individuals described below. The interview protocols appear in Appendix A. All interviews were recorded and transcribed. An average transcription is 25 single-spaced pages.

a. Students

Characteristics of the total student group in comparison to the interview sample are as follows:

by lecture by sex

Woods lecture

by gender

total group:	58 men, 27 women (85 total)
interview sample:	9 men, 11 women (20 total)

Wright lecture:

by gender

total group:	61 men, 44 women (105 total)
interview sample:	10 men, 9 women (19 total)

by TA section

Woods TAs:	2, 3, 5, 5, 5 (20 total)
Wright TAs:	0, 3, 3, 4, 4, 5 (19 total)

by college classification

	ALS	EGR	LS	total
total group:	31	60	99	190
interview sample:	6	11	22	39

intended major not yet selected

	ALS	EGR	LS	total
total group:	2	19	94	115
interview sample:	2	5	21	28

All 39 students in the sample were interviewed during March (findings reported in Formative Feedback #2). All but 4 of these same students were interviewed a second time during late April and early May (findings reported in FF#3). One-on-one interviews were held with 14 of the students. The remaining 21 students were interviewed in focus groups of two or three students.

b. Instructors

Two one-on-one (late March and late May) interviews were conducted with each of the 11 TAs and both of the faculty members. Two of the TAs were female.

c. Faculty Assessors[1] (not yet analyzed)

A single one-on-one (late May-early June) interview was conducted with each of the 25 faculty assessors. Four of the faculty assessors were female.

2. Briefing Meetings (not yet analyzed)

Three faculty assessor "exam preparation" meetings
Three faculty assessor debriefing meetings

3. Open-ended survey questionnaire information (not yet analyzed)

Student responses (all but 6 of the 180 students assessed returned surveys)
Faculty assessor responses (25)

4. Quantitative data

Student database records from DoIT
Student survey data (only a few items from these surveys were analyzed for this report)
Faculty assessor ranking data

Technical Information

1. Use of Verbal Quantifiers in Reporting Qualitative Data

Specific verbal quantifiers are used to denote the relative size of a group of participants who presented particular perspectives or described particular experiences in interviews. It is important to note that due to the nature of qualitative interviews, the size of a group that *discussed* a particular type of experience does not indicate the size of the group who *had* this type of experience. Although the same interview protocol was used in each interview, respondents' answers often prompted discussion on a particular area that may not have emerged in other interviews.

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[1] Detailed information about the design of the Chem 110 Faculty Assessment Project appears in Appendix B.

The verbal quantifiers used in this report are:

"a few":
used when up to 30% of those interviewed presented the perspective under consideration

"many":
used when 30 to 70% of those interviewed presented the perspective under consideration

"most":
used when 70 to 90% of those interviewed presented the perspective under consideration

'virtually all":
used when 90% or more of those interviewed presented the perspective under consideration

"a subset"
used to articulate more gradations within a group referred to previously by "a few," "many," "most," or "virtually all." A subset includes at least two individuals.

2. Presentation of Transcribed Materials

When dialogue is presented, students are denoted with "S:", instructors with "R:", and the interviewer with "I:". Boxes are placed around dialog to separate it from the other text. Ellipses (...) in quoted material indicate deleted dialogue occurring within the reproduced material. Deletions are made so that readers can appreciate the speakers' views on a particular topic without having to sort through the divergent twists and turns of the raw dialogue. The quoted material is presented as faithfully as possible to the speaker's intent. If additional text is necessary to understand the quote in context to the rest of the discussion, it is added in brackets.

Woods' Goals for Chem 110

Professor Claude Woods, along with his colleague Professor John Wright, believes that Chemistry Department goals for students in Chem 110 are understood in terms of a contrast with other first-year chemistry courses. In particular, Woods and Wright share the goal of ensuring that Chem 110 functions *not* as a survey course, but as a course that offers a challenging and stimulating experience for students who are serious about science and scientific thinking.

Woods elaborated in his first interview with the LEAD Center as follows:

> [My goals for Chem 110] are to make this an intense, total immersion, ... experience in chemistry and to make the students feel that the chemistry is interesting and to give them some idea of how professional chemists attack and think about problems... So it is not just a general survey type course. It is a course that is aimed at people who really want to learn how to do these things, who will be applying them later in careers, and so we try to make it challenging...
>
> ...I believe that we have felt the students in Chemistry 109 and 110 are maybe in the top 10% of students that take freshman chemistry, roughly speaking. Therefore they are the good students. They are the science and chemistry majors, and so this ought to be a really good intensive course in analytical chemistry.

He later elaborated on his goals:

> Woods: [I aim to] give students a feeling of how scientists talk to each other and how we think about a problem ourselves, and we tend to think that [a good method is] analyzing the problem mathematically, and relating it to the concepts...
>
> I: So you are assuming that, viewing them almost in some sort--as junior colleagues. It almost sounds like that that is what you are doing?
>
> Woods: Yes, that kind of thing...I am really thinking of this in the way that a music professor would be teaching a music student, not a music appreciation class...assuming that the student, by virtue of being a music student already, is interested in music, and they have made a commitment to it, and they would like to learn how to play their instrument better... I think that it is sort of a waste of time to try and lecture the students about how scientists think about problems. I think that it is better to just get up there and do it myself, and let them watch me think about it as a scientist would think about it.

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Woods Lecture: From the Students' Points of View

1. Learning Experiences Associated with Different Components of the Course

1.1 Lecture/homework/exams: a strong relationship.

Most students indicated that the lecture was taught with the homework in mind (see FF#2) and the tests assessed the students' knowledge of the homework problems. Most students placed great importance on homework in terms of learning chemistry and succeeding in this course.

S: I would say the problem sets have - as far as the class, what I've learned in class, they have been the most important...because that's where, as far as lecture goes and our exams, that's where that's centered on.

S: Well, pretty much our tests have come directly from homework. You know, we'll have maybe two problem sets, or whatever, ...and the exam problems, are directly from that, but maybe done a different way, or whatever. So pretty much if you can do the homework, you can do well in the class, and if you can't, you can't. I think they do take a lot of time if you want to do it and do it well and do it right. I mean, that's a lot of time. That's why we have the two weeks to do it. I think they're very important.

1.1.1 A step-by-step process: Woods "creates a process in our minds."

Students in Woods' lecture reported learning analytical chemistry and Woods' method of analytical chemistry in a very step-by-step process/problem solving fashion. The lectures were structured in this way as were the homework problems and exams.

The student quoted below related that Woods "created a process" in the minds of the students by which they did the homework problems.

S: It was entirely the homework. Without homework, geez, I don't know what test we'd pass. But that's the most integral part of learning chemistry...

I: The homework is then really the key thing here?

S: Oh definitely, to learning what you're doing, to understand - because when he gives us the lecture, what happens is he's going to present us with this concept, and it's through his homework that he presents the concept in different ways and different situations, and that's how it prepares us for the test basically. It helps you understand the concept more, 'cause his homework is really step-by-step. I mean, he'll tell us like, say, in the homework he wants us to understand EDTA titration, and he'll practically walk us through it - well, not really, but he'll create a process in our mind in which to approach the problem through his homework. Like, step A, create this equation, and in reality that's how you would start the problem, so it's kind of interesting how he does the homework, but it's definitely the homework.

Some exam problems started at some point other than the beginning of the step-by-step process. A few students said that they performed poorly on those problem because they either started at the beginning of the sequence out of habit or had difficulty starting in the middle:

S: A lot of people did very well [on the exams], ...and so I think that maybe it's just my, perhaps my study method...This last exam I understood the method, but I understood it like in completion, if I went step-by-step-by-step-by-step. Where on the test, obviously he doesn't give us one problem where you go step-by-step. He gives you maybe the fourth step that you have to do. So, I'm not so good at jumping to the fourth step without going through one, two, and three...

I: You have to back up.

S: Exactly, and then go through it a little bit so I can have complete understanding, and then I can do the step four.

A few other students said that they felt thrown off when the exams problems were unlike problems they had seen:

S: It took me--well I worked to the end of the period because... there were five problems, and I was able to do 1, 2, 4, and 5...It was mechanical. Just went right thru it. [On the other hand] number 3, I had never seen anything like it in my life. (laugh) I sat there for an hour. I was able to get half the points on it because I was able to do about half of it. You had to write down two equations and somehow relate it to these third terms that had nothing to do with it. I mean, from first glancing at it, had nothing to do with it, and I ended up getting a zero on that part of it, but, oh well...

1.1.2 Really thinking.

Many students indicated that doing the homework and the tests required them to "really think."

S: I have new approaches toward chemistry. Before, if it wasn't in the book I didn't know it. If he didn't present the scenario in class I don't know it. This chemistry class, I guess, forces you to have abstract thinking. It makes you ask yourself questions all along the way instead of just blindly copying the notes down, because if you do that, once you get to the homework you're pretty much screwed. Literally, because you won't know what's happening! It forces you to actually listen to what the prof is saying, his little explanations, even his little analogies toward life

S: First exam wasn't, I don't think it was too hard. It was basically based on the homework. Second exam was tougher...he like, well, it wasn't like impossible, but he made you think more on the exam. That was, it was tougher.

S: As far as the homework and lecture go it is hard to separate them. But, I think the actual learning, it was the homework that did it for me, anyway, because you actually had to sit down and actually do the problems instead of sitting in lecture jotting down notes and trying to listen. But, you actually had to sit down and comprehend what you were doing. I think that helped me the most.

1.1.3 Learning is a problem-solving process and mathematical modeling.

Many students emphasized that in addition to learning chemistry concepts in this course, they had learned a problem-solving process.

S: ...I guess looking at chemistry from an analytical standpoint has changed my view of chemistry a little bit--working out problems differently, there's a lot that goes into it--a lot more math than I had originally thought. Otherwise, I think, things are pretty much the same.

I: ...You say it helps you learn problem solving. ...Can you translate that problem solving ability over to other classes?

S: I think so...you definitely can. I think, because problem solving, whether you're solving any kind of problem, it's basic. You know, there's basic steps to all problem solving. so regardless of what class you're in, I think that it does help out, you know, because you know you have to find out what the problem is and have a plan to go about it. So I think problem solving--it 's an important thing in all classes, generally.

S: ...I like his style; the way he gets you to think. And the thought process that he; that he kind of takes you through I think is very important...It's very...straightforward...You get this complex problem, break it down, [and ask yourself]. "What do you know." And...everything that he's taught us I think comes from that. Just the way he lays it out for you. Umm, that kind of gets you to think that way and...it helps, and I think that that will probably, I'm sure I've carried that away from this class more than anything else. You know, I could have gotten acid-base chemistry out of any professor. But...I like the way he teaches. I like...the thought process that he encourages in that class.

A few students emphasized the value they placed on the mathematical modeling skills they had learned in this class:

I: Of all the different aspects of chemistry that you are exposed to in this course, which do you find to be the most interesting?

S: I would say it would have to do--it's not even necessarily a specific field of chemistry--it's kind of the idea of mathematical modeling. That you get a set of data, regardless of how you got it, and then what you do is you put it onto a spreadsheet or plot it out by hand and find a trend. And then interpreting information from that data. That's the part of chemistry that I've enjoyed the most... [A relative of mine does mathematical modeling in industry and] I never thought that I would actually enjoy what he does...when we did a little bit of it in high school I thought "This is the most terrible thing!" ...That's...just doing it in a math class. Now you do it with an application in chemistry...it sheds a whole new light on it...In terms of science it [Chem 110] sheds a light on how you go about a process--how scientists go about their work and about their life.

1.2 Lab.

1.2.1 Most students agree they are learning meticulous technique.

When asked if there was anything that would have been difficult to learn without doing it in lab, a female student replied:

S: Well I think I learned a lot of really good lab techniques. I mean it's the, the lab part is where I've learned the most. I mean even just learning how to use all the equipment that we're using and all that stuff is really good, I wouldn't of gotten that, obviously, without the lab.

1.2.2 Learning about theory is TA dependent.

Some lab sections were encouraged by their TAs to think about why they were performing particular steps in the lab process. Other lab sections did not learn the reasons behind the procedures.

The following excerpt is from an interview with two students, one who learned the "purpose" behind the labs through his TA's quizzes, and the other who did not have quizzes and "just did the experiment and the calculations" often without really understanding why.

S1: Yeah, s/he gave us. It was actually kind of nice. The TA gave us a list of the questions...from lab, like, "What is the purpose of adding this chemical at this time," and we would have to go and figure out what it was. And it was actually kind of interesting, actually... But we actually found out why the catalyst for some other reaction. It was kind of cool. And s/he gave us quizzes from that. So we had stuff to study from and they weren't too hard quizzes and it was kind of interesting.

I: Yeah, it sounds interesting.

S2: Maybe we should have done it [had quizzes] then. 'Cause, I mean, I feel... like, a little bit that, not everything in lab connects completely, well, not connects, but I don't sometimes understand completely what is going on in the reactions and stuff. [I] just do the experiment and calculations and that is basically it.

1.2.3 Cookbook labs provided low level intellectual challenge.

Even in sections where the TA encouraged understanding of the labs, some students said that the cookbook labs did not provide an intellectual challenge and therefore did not promote in-depth learning.

S: The labs, the lab is written out for you, but then the calculations, you kind of get led through the calculations, so it's not so much of the - you don't have to do so much on your own. I mean, you have to do the busy work, but...the lecture and problem sets are a lot more thinking on your own, and it's really something you have to do on your own, as far as chemistry goes.

S: ...whenever you're doing the lab I think basically you're just doing what it says. Because that's how they're set up, they don't make it real tough to actually carry out the procedure. You know, add 50 mills (milliliters) of this, and you probably don't know why. Because a lot of them are just chemicals you've never heard and, even if we know, there's, yeah I think there's just a limit. Because even if we know, "OK. I'm adding this because its going to reduce the iron." I don't know how. I don't know why this is reducing the iron. I've never heard of this before, so I think it's just you know, they're cookbook labs.

S: Lecture is there to learn the concepts behind everything. Lab you just kind of copy down some equations and use them, and you might ask what they mean, but you really just want to get the calculations done. You know, and in lecture we, you know you actually learn where it came from and why it works and that sort of thing.

Several students contrasted the unknown labs, in which they were not told how to accomplish the goal, with the cookbook labs, and indicated their preference for the unknown labs.

S: ...I think maybe that's a big part of it--I never really did like lab and I think its because you just do add stuff; you don't know what you're doing. And I'm much more into knowing how stuff works, than just seeing it work...and just this couple of weeks we've been doing a lab where we get this acid system and we have to determine--we know what it is--but we have to determine how much...is in there. And now that I know about it, at a more high level, the lab meant a lot more to me, and it was even fun to do. Because we didn't have, we weren't told, rather than not tell us what we're doing and just tell us what to do, this time we knew the idea behind it and we had to figure out what to do. And I got, I think that was, that was probably a more interesting that I've done this semester. Because we knew about and used what knew rather than the other way where we do what it tells us.

I: What would it be like for you if the whole semester had been like that?

S: I think I'd probably like lab a lot more...I would have a better attitude towards it...I just don't think its that much fun. There, the most challenging thing that you do in lab, most of the semester, is see how clean you can get a beaker, so that you make sure there's nothing in it to interfere. You don't have to think about it, you know.

S: It was really cool because one of the labs that we just did was like you get a little baggy full of stuff and they tell you what is in it. And you have to tell them how much you have. And I thought, Hey I can do an EDTA titration on this! And so I went to some analytical literature and looked up how to do the titration, what indicator to use. Which was actually kind of exciting to actually be involved in the process instead of doing a cookbook [lab]. I 'd like to see a lot more labs like that...The rest were all straight out of the book. Read the instructions...[and] I'd rather take a cooking class.

1.2.4 Learning new chemistry topics.

Many students said that they learned new topics in the lab and that lab gave them a broader overview of analytical chemistry than lecture:

S: ...Probably the lab [is most important for learning chemistry]... because we learn so many various types of chemistry. The lecture covers basically some very specific points. And you learn a lot in detail, in terms of just general chemistry knowledge and all sorts of different areas. The lab covers all sorts of different types of... areas of chemistry. And where you can learn just general [chemistry concepts] and technique. Laboratory technique. Basics. But you also learn a lot of what you would typically , I don't know, call lecture material, in lab. Just from the...The applications. And the theory behind what's going on.

I: Has there been any chemistry that you've learned in the lab that would have been really difficult if you hadn't done a lab on it?

S: Yeah, I think a lot of things that we do in lab, I mean, they aren't intentionally things we go over in lecture, and they aren't even things that are intentionally analytical chemistry, that I think lab is where I learn the most...like, what we're doing now is, like, my partner and I have a combination of HCl_2 and NaCl. We were coming up with different methods of how to figure out what percentage we have of each one. We tried one method and decided we really didn't like doing it that way, and we wanted to get more exact results, we were going to try a different way. Then we decided we didn't like that way cause we still didn't think we would be as exact as we wanted to be, so we finally came up with another way...[Our TA] was discussing, you know, do the tetrahedral formation...and all this stuff. It made complete sense, but it's probably something I won't learn for three or four years...I think there's a lot of things we do that we don't actually have a name for it, but if we'd read all the chemistry books, or whatever, we'd be like, wow, we know that and that and that and that. So I think we learned applications of maybe theories we don't even know, or just things that we don't even know.

S: I guess we covered a lot more, we cover a lot of stuff that we don't cover in lecture. Maybe a lot more than I realize. ...Like spectroscopy, we didn't talk about that in lecture. But I know a lot about spectroscopy from doing the labs. And that stuff is interesting. And even if...even if I didn't get a kick out of doing the labs, ...you can't not learn about [these things], you know. ...I think you do learn a lot, because, not as in-depth as some of the things we'll pick up on lecture, but you do get a sense that you have a really, overall good view of the things that they can do in lab.

1.2.5 Almost universally positive reactions to unknown lab.

Virtually all of the students expressed great enthusiasm for the unknown labs. They valued the opportunity to test their knowledge on a lab with a goal, but without a set procedure for reaching the goal.

S2: I spent a lot of time in the library researching picking up journals, and helped me use the MADCAT a little better, to find different things. We had the head of the Chem library trying to find stuff for us, and we tried about three different procedures and we found out that they didn't work and then we found out why they didn't work. It was a case of using a strong inference method of proving a this wrong, or we can't do this. Then we will have to use that. I found that really interesting.

S3: I felt like a scientist rather than just a student. I think we are getting to the point where we can actually do the stuff on our own. Where we can be expected to find our own procedures. Where they throw something at us and we do it. I really enjoyed that lab. I was upset when it was over, and I didn't have anymore to do.

I: Of all the different aspects of this course, or aspects of chemistry that you've covered in this course, which is most interesting to you and why?

S: I guess pretty much just the lab, cause I just love being given a problem and finding a solution to it and figuring it out. I mean, I love the actual process of figuring it out, and lab allows you to do that...I mean, I love the fact that we're just given two unknowns, and this week, "Okay, [you have] six lab periods [to] do whatever you want. This is what you need to figure out." I was just so excited. I was like, "Yeah, we get to figure stuff out!" I opened my book, I looked up different charts and different tables, and just solving the problem was a lot of fun, rather than just learning the problems.

One student who had felt she understood very little in this course said that the unknown lab gave her the confidence that perhaps she wasn't "clueless."

S: ...And we just did a couple labs where we just basically got unknowns and just had to do something with them and ah, that kind of scared everyone. [Laughter] I think at first cuz we were just standing there with these little packets of powder going, [Laughter] "OK!?!" But um, now that I finished that we've done it, ours worked, we figured out what we were doing, so that was...That was good, it made me feel like maybe I did have a clue about what was going on in at least one part of the class. [Laughter]

1.3 Relationship between lab and lecture.

Students' perceptions about the relationship between lab and lecture varied. While some felt that connection was close, others felt there was little overlap between the two. Opinions varied about the necessity and feasibility of connecting the two.

1.3.1 Lab and lecture are not closely related, and that's the way it has to be.

Many students said that the lab and lecture were not closely related and felt that this was logical because of the nature of the lecture material. They expressed that because the lecture material primarily addressed one phenomenon it would not be logical to concentrate solely on lecture material in lab.

S: I guess there is sort of a gap between lecture and lab. Sometimes what we do in lab, often what we do in lab isn't really near what we're doing in lecture. At the same time, what we're learning lab is basic important stuff that we should know. I guess with, with the lecture it's a lot more of describing chemistry through mathematics and [in] that way it's a little more theoretical. I guess in one way, in lab we can still ask our TA questions about lecture so that kind of ties it in a little bit. I don't know, I guess I feel like there is a gap between lecture and lab but I don't know how we could really do in lab what we're discussing in lecture.

I: Why?

S: Because now we're really working more, I don't know it's like we're doing the same thing the whole semester sort of in lecture. We're still describing chemical equilibria, we're just doing it in different ways and the only thing we could do in lab is just throw stuff into a beaker everyday and [laughter] and try and describe what's happening, I don't know...

This student went on to state that in lecture "what you're really worried about is the equation" and that in lab "it's just different topics in chemistry" learning lab techniques:

S: In a way it's, why bother [laughter] no really, because in lecture basically the set-up for a problem is...we have a weak acid of this concentration, let's try to describe what happens if you put these things together. And we come up with an equation for it and we work through and we decide what the concentrations of each thing would be, of each species would be at different points during a titration for example. And to do that in lab it would be, it would be sort of simplistic to do it in lab because you're not, what you're really worried about is the equation, it's really math that we're doing in lecture. To go into the lab it would be kind of silly...I don't know, but what we're doing in lecture would be a very, very simple experiment to do, just to see what happens. You know and lecture it's really thinking about it, coming up with equations to describe what's going on. I just don't see how we could really be doing that in lab. It's really, it's like in lecture it's math that we're concentrating on sort of. In lab it's more of just different topics in chemistry using- learning to use different equipment.

Another student expressed a similar thought:

S: [The separation between lab and lecture] It...it's good in some ways and some ways it's not. Sometimes it would be nice to see what were doing....in lecture..see it applied in a laboratory setting, but then again... really what were doing in lecture isn't anything that you can really see or observe in a laboratory area specifically because it's, you know, just mixing two chemicals together, and knowing what their concentrations are. And it's nothing you can really do in lab.

1.3.2 Lab and lecture should be more closely related, and were at the end of the semester.

A few students felt that the lab and lecture should be more closely related. These students appreciated the greater connection between lab and lecture that the unknown labs created. (This issue is also addressed below in 2.1.3: "Closer relationship between lab and lecture is related to unknown labs.")

S: And I think probably that, if we had talked about umm, well ahh, if we had talked about this in lecture first, the labs, a lot of them would probably mean more. If you'd understand what you were doing. And the only example I have of that is we did, before we talked about acid-base chemistry in lecture, we did this titration of an acid to find out what it was in lab. Before we talked about it in lecture we were doing the lab. And so it was just like a regular dumb lab you're just doing it OK we're going to watch the pH meter and there's an endpoint and then we're going to let our TA tell us what the endpoint means because we don't know; we've never seen this. And ahh, so I just did the lab, it really didn't mean that much to me. And ahh..then we talked about it in lecture. And learned all about it. I mean we learned, like what this titration curve is and really got into it.

The following student said the connections between lab and lecture were associated with the assigned readings.

S: [Chem 110 is] going really well. Everything's kind of beginning to make sense, cause I know, like in the beginning, I really felt that there was a big discrepancy between the lab and lectures, and it kind of all came together the past couple weeks. I know it's what we finally get to, but I kind of wish, you know, had we learned what we learned in the past week or so, or at least the chapters we've covered in the book, at the beginning of the semester, all the labs would have made perfect sense, or the reason why behind them.

I: What do you think the affect has been that it came so late, the connections?

S: I think it's fine that the connections came that late. I mean, it makes sense to me now, why we did what we did, but I always like to know as I go along too. I mean, I'm glad it finally came. I was pretty much like, yeah!, I understand what we're doing now, okay. So that's been a nice change.

A student who spoke at length about lab and lecture being mostly unrelated until the unknown labs went on to explain the importance of lab and lecture being connected:

I:...Is there anything in lab that you learned in lab that might have been difficult to learn without doing it in lab?

S: Definitely. I'd say the titration curve, for one, that we're doing, a plot--the creation of titration curves, theoretical titration curves, based on different scenarios, EDTA scenarios and acid-base scenarios. I think we definitely needed to see what those looked like in lab before we got into them in lecture. If we hadn't, we wouldn't know what to expect. I mean, we learned basically what n-point was in lab, and while we discussed how to get n-point in lecture, basically was the idea. I guess what we took from lab was explained to us in lecture...I mean, it's like a book that you read and you've never seen a demo of it. They'll explain it to you, but if you don't see it, then you don't know what they're talking about.

1.4 Discussion section.

For some students, quizzes in discussion provided a chance to think about why certain reactions occurred in lab. (See 1.2.2: Learning about theory is TA dependent.)

A few students conveyed that discussion section was not an essential part of this course. This was due to the fact that there was ample time in lab to ask questions of the TA and talk with other students, or, in some cases, because discussion was optional.

> *I: Is there one (component) that's the least important for you as far as learning chemistry?*
>
> S: Discussion, because pretty much any questions I would ask in discussion I'm also able to ask in lab. You know, I generally finish lab pretty early, so I can use that time to ask questions. I'm normally much more awake at that time and able to understand what's being told back to me. And discussion's generally just a time where we ask questions about lab or our lab write ups, so I feel I can do that in lab, so it's not as important.

Students from different lab sections are quoted here:

> S1: Technically we were required to [go to discussion]. The T.A.s didn't mind too much...
>
> S2: It was at like 7:45 in the morning. That is pretty early for most...Well, at the beginning of the year, I didn't go too much, but then I felt like obligated that I had to go. Plus, sometimes we discuss the labs in there and homework, so...
>
> S1: Yeah, sometimes I went and it was pretty helpful. Or we had to take a quiz. But sometimes it was just kind of pointless to go... S/He really didn't talk about a whole lot. Like s/he would introduce the next lab a little bit. And talk about a little of the theory that was involved, but not a whole lot. It would be kind of like, "Oh, all right." Yeah, he would pretty much just reiterate what was in our lab book. That's kind of dumb.

> S: Yep. It's entirely optional [attendance at discussion]. Our TA is the only one who doesn't want to give quizzes to his students...[the TA] uses that time to answer any questions you have....and the TA tells us the lab before, what s/he's going to talk about, and if you want to come--go ahead. If you don't, the TA says "Sleep in!" In fact most of the time the TA tells us "Don't come so [I] can sleep in!"
>
> *I: (laugh) What's the attendance rate? Is it....*
>
> S: It's about half. And I've gone to about half of them. The other half have been things that I've already done, or haven't needed help on...

2. Difference between first and second half of Woods' course

2.1 Especially positive reactions to the unknown labs.

2.1.1 Increasing frequency and importance of informal group interactions: linked to unknown labs

Many students related that toward the end of the semester, their interactions with other students became more frequent and important.

S: Mostly in lab, ...We've gotten to know each other and so it's a lot more friendly basis...and its a lot more open... I mean at the beginning of the class I could maybe talk to maybe two people in our lab, and now I talk to everyone...Part of it...is promoted by our TA, just because s/he has such a laid back atmosphere...it just forces you to relax...and just makes the four hours bearable I suppose....is just one way of putting it. Also, we've done about four, five labs where we work together in groups. And a couple of them he's assigned. And a couple of them we just, you know, choose our groups. And...just over the course of time it was just a gradual trend...you just start working with all sorts of different people...

S: [My group has been] more open to other people. You know, we're looking for advice from other people. I guess in a class like this you can't--I've seen people work alone, and I know a person who does work alone chooses not to interact, and he doesn't do very well. When he's got a question, he doesn't really have anyone to turn to, and you just work faster when you have an interaction, you know. You work off of each other's ideas, and then after a nice, you know, flow of ideas you come up with the solution, whereas if you're working just as one person, it doesn't work. So, I mean, our little clique, I guess, has to open up. You can't avoid it. The people there are nice, so, I mean, what can you do. But I think it's great, personally.

Many students linked this increased interaction to the unknown labs.

S: When it comes to lab, the same thing. I mean, we're trying to help each other out - at least, I think, in our lab, at least. With the people I've interacted with other labs, you know, we're going together and solving these problems together. You know, "what, you have the same unknown as I do? Let's do research together and share our info" basically...we found our own partners in other lab sections that we talked to who had the same unknown, and we basically searched these people out. I know that the TA's--okay, the whole, ideally, we're just supposed to just based on us two we're supposed to figure it out on our own. They know we're interacting, but they're not going to say it, you know. It's one of those things where it's understood we can work out. It's not like bad that we work with other people other than our...

S: Especially now there's been a lot of interaction between everybody. Like, people who have the same unknown's will be talking to the other people who have the same unknowns, what are you guys doing, did this work for you, are you going to do this.

2.1.2 Students had a chance to test their knowledge in the unknown lab.

This is discussed at length in 1.2.5: "Almost universally positive reactions to unknown lab."

2.1.3 Closer relationship between lab and lecture is related to unknown labs.

The following two excerpts from Woods' students represent the general reactions of all those interviewed. They found that the unknown labs helped them make connections between lab and lecture.

I: Interesting. Since the last time we talked, do you think that...this disjuncture [that you spoke of last time]...between lab and lecture, has this changed at all?

S: Recently, I think the gap has been closed up a bit, because, well, in the beginning of our lab we were doing things totally irrelevant to our lecture, and it's just because in our lecture, I think, we were just starting out with Dr. Woods' method. So basically while in the beginning of lecture we're getting introduction to this method, whereas in lab we're just learning to use the lab equipment and getting familiar with more of the advanced technology. Of course there'd be a large gap between the two, but...now you can look back and say yes, there is a relationship here, because definitely...Woods' lecture on acid-bases. If he just wrote it out on paper, how he'd figure it out, whereas in lab we needed the actual experiment to figure it out.

I: Okay, so you needed to see it.

S: Well, yeah. You had to basically perform the experiment, and now we know how to do it without having to perform the experiment. But definitely now, cause in lab we're doing unknowns--unknown weak acid systems and also unknown acid compounds, I don't know, mixes I guess...And they don't give us a cookbook like usually to figure out the things that they want to know from our unknown. So, what we have to use isn't just lab, but it's an integration of what we learned from lab and what we learned in lecture. So I guess right now the lab that we're doing is an all-encompassing, and I guess this would be the joint between our lecture and our lab, what we're doing right now.

I: Okay, have your feelings about any parts of the course changed throughout the semester or since the last time that we talked?

S1: I think that my feelings about lab have changed. Because, recently we have started to do this big project where we had this weak acid and we had to figure out what was in it and then this other solid. We had to figure out how much of what was in there... And so it applied more to the course, I think. As far as at least the weak acid part, because we got to use some of the stuff that we talked about in class and I thought that was real neat. And, we're still working on it, and I like that they did that. It's pretty neat.

I: So at the beginning of the semester you felt how about lab.

S1: Well, it was...

S2: It had nothing to do with...nothing to do with lecture or the homework. It was like it's whole separate part.

S1: And just this last project they really related it a little bit at least.

I: So you say a little bit. So it hasn't been fully integrated.

S1: No, not fully.

S2: ....Instead of...telling us what to do, we kind of had to design our own procedure,.how to find out, he doesn't want you to just do the experiments, because we just have to find out what it is... But...it somehow relates it a little bit to what we are doing...

2.2 Increased use of textbook.

A few students said that toward the end of the semester they were using the textbook more. Woods had assigned readings and those who reported having read those sections found the reference valuable.

S: Well, for awhile things didn't change at all, but...in the last couple weeks I think we didn't change, but I think that because the things that he's moving into now I have a firmer background in, and there's more reference, like he's following the book as well, so I can understand...

S: ...I learned stuff from them [the readings], but I think if we had read those four chapters the first day of class, everything we did this year would just have made so much sense, cause I guess the whole basis of where we've been going is to get to electrochemistry finally, and this starts at electrochemistry and then goes back and shows how the titrations did this and how this did this, how that did that. I was like, wow, this would explain why this worked in lab and why this didn't work...I think maybe if he'd said at the beginning, "OK, we're going to electrochemistry." You know, "These are the components you need to know to get to electrochemistry." Had that been said up front, I think the entire class would have made more sense.

A few students indicated that it was difficult to use the book as a reference because of the differences between Woods' method and the books' method.

S: I mean, homework is basically our lives. I can tell you this because we were working on homework last night, and it's only two questions, but it took us a total of about six hours to figure out both questions. And it's not so much that we don't understand it, but it's so much that we'd have to go through our notes and refreshen our memory of what we'd learn and do it in the style that we've been taught, cause they do present a style in the book which we could use, but that's the long way and also the inaccurate way, from what we've heard. So that was just - that's probably why it took so long.

In the following interview excerpt a group of students from Woods' class recommend that Woods write his own book:

S1: There is some good stuff in it though. Its hard sometimes to put together what is in the book with what Professor Wood's says, because he has like his own method for doing all this stuff. I think he should write his own book actually. [Laughs] it would be a good book.

S3: I like his methods but, and it is so hard when there are no references. All you have for references is your lecture notes.

I: Yeh, tell me more about that. It seems to be a pretty big concern for most students. What it is like not to have a reference.

S1: Well, I think it takes a little work, but you can piece together the book if you piece together the book and the lecture. I mean, if you resolve the differences in nomenclature, and the differences in the way they derive the different equations. Its a little work. You may have to put in 20 minutes or a half hours for each problem of re each problem that you do. But the problem takes two or three hours or so, its not, its worth it, to get more understanding of about how it works together. Not just hit and miss, and try to guess from the lecture notes.

2.3 Rushing at the end to cover planned content.

Many students felt that Woods was rushing toward the end of the course to get to the planned content. These students felt that their understanding of electrochemistry, the last major concept Woods dealt with, was less solid than their understanding of other concepts addressed in the course.

S: What has frustrated me? I don't know. It's basically the same thing that frustrates me about any course. With the closing of the year professors try to rush and get everything that they think we need to know in time to keep up with the other classes, and I guess it's especially important with this class because of that trial and control thing, so I don't know. Right now I feel kind of rushed.

S2: We have a problem set, the longest one he's ever given us, and it seems he is basically just lecturing so we'll be able to do the problem set. Which I suppose is. I guess he has to. I don't like it so much, because I think we are kind of missing some stuff.

I: Like what?

S2: I don't know, we're going electrochemistry now. I've been told by millions of people that it's really important that you know this stuff, this is really important. You are going to use it later. I don't know, we're just not spending a lot of time on it. And I don't feel like. He goes by it really quickly, and I don't feel like he has a really solid grasp of it.

A few students expressed concern that there were several important concepts that they expected to learn in Chem 110, but had not.

S2: Possibly, that I think there were something we haven't got to, that I think I'll need later on that I will have to learn later. I guess, the inconsistency of speed. Just recently that he sped, up, as opposed to like, before, when he'd go really, really, slow. It sort of started off really slow, and every lecture I'd be fine. And then after the first exam, things kind of sped up a little bit, Because he was running out of time, and after the second exam, Wow. So, maybe that, but really, but I wouldn't actually say that that's frustrating.

I: What are those things that you think that you need to be covering?

S2: Oh, I don't know, Did you guys [in Wright's class] ...do gibbs free energy...and stuff like that. [Wright student nods his head.] See, we never did that. And that's kind of important, and we never did entropy...And now we are just getting to electrochemistry.

2.4 Professor expected students to remember more, and gave less explanation.

Many student noted that Woods expected more of them as the semester drew to a close. They felt that he skipped steps in his explanation because he assumed they had knowledge from the previous material that applied to the correct subject at hand. Some students felt comfortable with this and others did not.

A group of students who felt comfortable with the speed of the course at the end and with the references to previous material are quoted below:

S1: I think he is moving a lot faster because we are doing basically the same things, just with different things. We are doing titrations in electrochemistry, we do titrations in complexing agents, we did titrations with acid-base, just basically we are looking at different ways to do analytical chemistry.

I: So you are drawing upon everything that you learned before?

S1: Yeah, if you've got the basics down, like how to derive the equation from the whatever, then you are doing pretty good. If you memorized just how to do one, for a test or something then you are probably up the creek.

I: If you didn't get the underlying concepts?

S1: If you caught on to the method that he was using right away in the very beginning then it is pretty simple. But, if you missed out on what he was trying to do, then the it was going to be like the general set up for the entire semester, then you've got some catch-up to do I think. I think if you really understand the basic principles behind doing titrations behind analytical chemistry, then you can apply other things you know to get anything you need to derive.

S2: In this class there are 3 main kinds of problems and everything builds on all of them. If you don't understand those three, everything for the whole semester is then twisting them around.

I: Are there some people who are just floundering at this point? Sounds like that can really happen.

S1: It seems like on the last exam there were a lot of A's and B's, and then like a lot of D's.

The following quotes are from students who struggled at the end of the semester, because they were unable to follow Woods' explanations when they were not step-by-step:

S: I think his explanations are to the bare essentials, and we're not spending enough time using different scenarios, and he's not spending enough time, I guess, explaining, you know, to the bare bones why this is and why this is. Before, in the beginning, and I thought this was very helpful, he was explaining to us the whole concept of log. You know, how you take the log of something. What's the log of one? Everyone's like, zero! And that's how basic it was getting. Now I guess he just assumes we know what we're doing.

S: ...it doesn't seem like we're- it doesn't seem to me that we're doing anything that much more difficult now but I'm having a hard--maybe it is the speed that we're going. Ahm, you know it maybe that's what it is because it doesn't seem to me like we're doing anything that different from what we were doing [in the first part of the] semester. But now I think Professor Woods expects us to catch on faster because we should be more familiar with these, with this sort of problem...that's probably what it is [that makes it more difficult for me now] is the speed that we're going at now. Umm, we're expected to be able to pick up on these problems faster and I'm still kind of working at the beginning speed, I guess. Umm, ...we do move kind of quickly through the problem and there's a lot of substitution, ...we learn different ways to describe, say the concentration of something, and we do some quick substitutions in the problems, and I don't always catch where that term came from. I guess I am having problems, you know, remembering where everything came from in the equation, how it was derived and I guess that's, you know that's part of the problem I'm having.

S: I could follow up [until] like, when we [interviewed in week eight]...I could follow his lectures and how he was doing but now it seems much harder to follow and he expects us to realize a lot of the really, a lot of the simpler stuff which is a base of all the harder stuff we're doing and I don't understand some of that so it makes it really hard, a lot harder...also the notes aren't as complete now, he seems to like to be jumping really quick, making big steps, and I don't...I find myself not really following the exact logic that he's going through because he skips a lot of the basic steps cuz he assumes we remember all of it but a lot of the times if he would just say a really brief description of how he got that, then it'd be much easier to follow.

3. Character of student-student interactions.

3.1 Varies for different people due to laissez-faire nature of group formation ("cliques").

As students were allowed to work either in groups or alone for much of the course, students' relationships with other students varied in character. Students often had to work in groups in lab because there was limited equipment, and this fostered some of the student-to-student interactions.

3.1.1 Classwide Issues

3.1.1.1 Classwide cooperation experienced by some.

A few students indicated that, especially toward the end of the semester, the whole class cooperated and interacted.

S: [I sit in the] Second row...And I used to sit with a clique of about three people. I don't think it's so much cliquey anymore. I mean, okay, we're still good friends, and that's just how it's, you know, based on the lecture. We're interacting between rows and people I've never talked to before were asking questions to people they didn't know, people we don't know are asking questions to us, and we're giving each other answers. And that's good cause I feel like it's not individual competition, but all of us are basically trying to pull through this and I think that's great...

A few students related this classwide cooperation to the unknown labs.

I: Would there have been anything difficult without interacting with other people?

S: Oh my gosh, all of it would be! I mean, I guess our class interacts a lot. In homework, in tests,, in lab definitely. I think our lab's the closest personally. But yeah, definitely! In lab right now, since we're not given a method [in the unknown labs], basically all of us--not even in just our lab. I mean, it's between labs too. We're discussing our methods, you know, our ideas, and the interaction definitely is necessary because it presents you with more than one viewpoint definitely, and maybe the TA's. Because there's a difference in TA's. There's definitely a difference in knowledge or conceptual thinking. So the interaction between those two, then you just end up with a lot of options then. So definitely now there's a lot of interaction.

3.1.1.2 Some students only know others near them in the lab.

A few students indicated that they only knew a few people in lab, those that worked in their proximity.

S: You know when we worked in groups and you know there's two girls on the other side of the lab that I'd never even talked to that asked if I wanted to be in their group so I met two new people. Cuz really, in the lab you know you talk to the people who are just immediately around you...So that gave me a chance to meet someone new. And actually it is kind of crazy that I don't even, I don't think I know the names of some of the people who work at the other lab stations just because they're far away, I never talk to them. ...I guess we're all kind of, you know, we're kind of getting more comfortable with each other, talking to each other...We worked in groups just because there's a limited, there are a limited number of equipment, so. That's really the only time we ever work in groups.

3.1.1.3 Some dependence on others for answers.

A few students said that certain class members tended to ask frequent questions of other students and seemed to rely on answers from others rather than "thinking for themselves."

S: ..In my opinion we try and help each other out, and I think - I don't know. I know I find it infuriating. There's a couple people in the class who just consistently, always, always, always ask questions. It's like, "Start thinking for yourself," cause you want to help them, but you don't want to sit there and be like, "This is how I did it, and this worked out right, so you should do it this way too," cause there's more than one way to do it, and they have their own ways of doing it. Believe me, in the beginning, I have no idea if what I'm doing is right or not, so I don't want to mess other people up, or whatever. In that sense I try not to be too helpful, and sometimes if I'm really concentrating on something, I get really frustrated when people continually, constantly, are like, oh, yeah, "What's this?" or, "What's this?" I know especially if [my friend] and I are working it's just like, "Come on, we've got to get this done!," and everybody's like, "Aaaah!"

3.1.2 Group Issues.

3.1.2.1 Group interaction valued by students who had good groups.

Many of the students who we interviewed had formed groups or "cliques." They said that the support their groups provided them was invaluable in learning chemistry. These students also expressed a higher degree of satisfaction with the course than students who had not formed groups.

3.1.2.2 Improved learning through multiple perspectives.

The students who had formed "cliques" expressed that they valued the multiple perspectives that their groups afforded them.

> *I: Were there any concepts or topics covered that would have been difficult to grasp without having other people around?*
>
> S: Yes, definitely.
>
> *I: Tell me about that.*
>
> S: It's hard to say a specific concept, but a lot of things..., just, I think, different ways people learn. Some people got certain parts, and I certainly didn't, so they helped me along on it. I don't know if I ever helped them along. I hope I did, but there's definitely - I wouldn't have understood a lot of things if I didn't have other people around.

> S: Occasionally, like before an exam, you know pretty much what's going to be on it. But there's going to be something like, you kind of, you know how to do a problem, but you don't necessarily understand what the theory behind it is [i.e.] why something equals something else, and you're not sure why, ...Generally, there's always someone who knows the answer to one particular area, you know, not everyone knows everything, but...with the culmination we know pretty much [pause] everyone together knows pretty much everything. So...having that benefit, you can, that you can always ask someone and someone going to have the answer...or at least someone will be able to explain it in a way that you'll understand it....

> *I: Were there any topics that were covered that would have been difficult to grasp without having other people to help...*
>
> S: Well, I think a lot of the, we did a lot of solubility stuff and equilibrium the first half, or first three-quarters. And I think, what was I going to say... Having other people, it helped a lot, but I think it would have taken a lot longer to understand it than to go ask your friend and have him try to explain it to you. It would have taken a lot longer to do it by yourself and it really helped a lot to having people around to ask questions.

S: I guess learning alone can be very difficult. I guess I can't pick out any topic in particular but just discussions that we have in lab. The TA asks a question, we all come up with possible answers and we use each other a lot...I couldn't learn half this stuff without other people around just--they think of questions that I didn't think of. They'll ask a question and I'll realize I didn't even realize I didn't understand that until someone else asked about it. And just a lot of times in lab I'll be confused on one little thing, I'll ask the person next to me, he'll know. I'm like, "I'm going again, I'm fine." There are so many things that could trip me up where I just need to ask one question, someone else explains it really easily and oh, it all makes sense now. You know, we use--other people are very important.

3.1.2.3 Interdependence/Self-reliance.

Students with good groups described their groups as being characterized by interdependence and self-reliance. Many of them indicated that their approach to assignments was to try to work them out themselves first and then ask questions if they were stuck.

I: Well describe to me a little bit how...how you might go about...problem solving...What goes on?

S: Well, for me personally basically first I try to solve it myself. And if I can't do that, I will...like let's say we're making a graph something. I'll compare the graph with someone, see if they look the same. If something's wrong then we'll compare our equations, in the different parts of it, and if that doesn't work, I mean, I'll do this with about three, two or three other students. Basically, I go to the students first. And then maybe my...and if I'm really lost and no one can explain it to me, then I would go to Dr. Woods.

S: Well, with some of the homeworks, I had four other guys on the floor. Or, me and three other guys in the class. And usually, we would all get the homework and we would start looking at it by ourselves and try to figure out what was going on and trying to get a general grasp on what he was asking. And then, we would get together, and, usually just me and one other guy, and the other two would be off on their own and they would come ask us questions and stuff. And we would get together and work out the details of it. And, sit there by ourselves and do it but then when we had problems, ask each other questions and you know. And after a while we slowly work out the whole problem and get everything answered and everything clear in everyone's mind. And so, that is pretty much what happened usually, with homework.

I: And what was the best part of that process that helped you?

S: Well I think knowing that when I was stuck, that I didn't just have to sit there and grind out an answer. I could go ask someone, and, you know, get some help in getting it clear instead of just being by myself and not knowing anything.

S3: Well, instead of working alone I get to work with a group of friends that I've grown closer to over the semester and if I'm stuck way late at night with a problem in that I've- I usually try to spend a fair amount of time on it first and don't give up and just call and say hey, what'd you get? What's the answer? Ahm, and when I do call them it's more like, well what steps did you take, not necessarily give me the answer and just insist saying, well you know I did this and this and this and then I got this. What did you do for these steps? And they, we help each other.

I: Yeah, what does it do for you that you have, in a sense, you have a support system?

S3: It's helpful. I mean I know that when a problem set's gonna be due, or when it's due I'll have it done because we've worked together. And I know my friends rely on me, I rely on them.

S: ...I signed up for this class with my best friend...We talk on the phone about chemistry just about every night - it's like, what do you think of this theory?, or whatever - and our little two person group expanded to four now, so we have four of us constantly putting our inputs in. So things become pretty clear pretty quickly, but it's also, you know, one of us is chemistry, one's chemical engineer, one's biochemistry, and one's just doing pre-med and doesn't know what to major, so you have the four different perspectives and four different viewpoints coming in on it, so what's right and what's wrong becomes pretty clear really quickly, so I feel I'd be able to grasp most stuff right away, because even if I'm wrong I'm quickly corrected and shown why I'm wrong.

3.1.2.4 A few students remained isolated.

A few students that we interviewed indicated that they had not made friends in Chem 110. For some, this was not a problem, as they felt highly confident in their chemistry abilities. For at least one student, however, this meant that when she was "stuck late at night" she had no way of getting help. This student was not doing well in the class and relied on her TA, who provided a great deal of help.

I: ...So what about you, do you have a group of people that you study with?

S1: Ahm well no because all of my friends from 109 dropped down a level, so...[Laughter]...So I'm doing most of it on my own...It's hard, it's hard. I rely on my TA a lot, my TA is great so it works well.

I: What, do you know what specific- what was specifically so difficult? ...

S1: Yeah, the connections are difficult. Ahm, you know it's just every now and then I'll miss one of the logic steps...I've been stuck a lot. And I have spent very many late nights, you know, just trying to figure it out and just getting absolutely nowhere, ... [And when I'm stuck I] keep going over my notes. I go over old stuff, um, if that doesn't work I just go and talk to [my TA] [Laughter] you know, I mean that's how I deal with it, but it's usually after putting in a lot of time on my own and not getting anywhere and being very frustrated.

The above student is in a lab where she is one of a handful of female students. She finds the group intimidating and feels like some of the male students literally "know everything."

4. Character of instructor-student interactions.

4.1 Professor encourages students to interact with him during and after lecture.

A few students said that they felt Woods encouraged them to interact with him during and after class. Some students interacted and others did not.

S: Our 110 class I consider very small, and when our prof first presented the idea that we were supposed to be interacting, sure we did it, yes people answered, but it takes a lot of coaxing. It took a lot of coaxing, it took a lot of whispering, you know, those half raising the hands, you know, "I might know the answer." Now people are actually joking around in lecture. I mean, they're answering freely, they're throwing out answers, they're throwing out ridiculous answers, I mean, just for the heck of it. I think it's more carefree and liberated, but I see that basically in, say, the first four rows. I don't hear very much from the back rows. There's one guy in the back row which I hear talking, and he's about the only one who's a consistent talker from back there, from what I hear.

4.2 Course setup requires students to rely on the professor as a source of authority.

Various features of this course caused the students to rely on the faculty as the source of authority. These features included the lack of a syllabus, some uncertainty about the grading structure (that eventually was cleared up for most students) and discrepancies between the professor's and the book's problem solving methods. While most students did not express concern about these aspects in the second interviews, a few did.

4.2.1 Professor as the content authority.

Many students indicated that they recognized the professor as an authority in his field and respected his knowledge.

I: What's the one thing that you've enjoyed most about the class?

S: About the class? Oh, there's too many. It's the prof's closeness to the students. I mean, he interacts with us. ...We're not afraid of asking him some questions. We're not afraid of correcting him if there's like some minor error, like addition or something. We're not afraid of him. I mean, yes, we think he's brilliant...and yeah, we take everything he says as the word, you know, you can't refute what he says. But we're not afraid to come up and ask why, ...because when he answers us he doesn't make us feel stupid, even if it is a stupid question. Literally! There was a question where someone asked--you know how there are three states of matter--gas, solid, liquid? Well, someone asked, "Is gas a liquid?" ...And that was just a really basic, basic, before 109 kind of chemistry in high school kind of question. And he said, without making fun of the person or anything, "No." Just "No." He's not like, "No!" [negative emphasis], that kind of thing. He didn't make the person feel stupid. Of course, the person, once it came out of their mouth, just automatically felt that way cause you could tell by the blush. Even a question like that, and even afterwards he felt the need to clarify for that person in case the person didn't realize what they just said, that a gas is not a liquid. And I thought that was really nice that he wasn't picking on him, but in fact took it that if the person really didn't understand such a basic concept he would clarify it anyway. And I thought that was great. And he even comes into our lab, and I think that's great, and he talks with the students.

S: ...well for one thing our professor I think is probably brilliant. I've heard that around and it seems clear...I like going to college because I feel like the people that are teaching me, really have been there and done it. More than high school teachers have. And that's part of what I like about it. And...when you respect your teacher you're probably going to be a lot more interested in what he's saying. And you'll probably listen to it more closely. And pick it up a little quicker. And trust him, you know. And know that he's not just getting this out of a book but he's probably had something to do with it, you know.

4.2.2 No syllabus.

A few students said that they were still concerned that there was no syllabus for the class and that they were unsure about which chemistry concepts the course would cover and when.

The following student, who felt particularly strongly about this, said that she felt "blind" in this course.

S: ...I still feel lecture is...kind of disorganized. I mean, there's no syllabus to the class or anything like that, but I'm getting used to it, so it's not as big of an issue.

I: What is the issue, then? What affect does that have that you don't know?

S: I like to see where I'm going in a class and why I'm taking it. You know, being able to say, "Wow, okay, I know," you know, whatever type of unit is coming up, and I know I know absolutely nothing about this, you know, "Let me read the chapters before I go to class," and that's something that I would do, and I don't feel like I have that ability with that. I think - I don't know. I guess Professor Woods generally explains things pretty well, but still it's like, you either get it or you don't pretty much.

4.3.3 Still some lack of clarity on grading procedure.

A few students indicated that they were uncertain about the grading procedures for this course. (In the first round of interviews, many students expressed that this had been a primary concern at the beginning of the semester. By the end of the semester only a few students expressed this concern.)

When asked what his expectations for the oral assessment interviews were, a student related that he was unclear about how they would be graded and said this was consistent with the lack of clarity about the grade structure for the entire semester.

S: ...That's the weird thing, about the whole thing in 110. We never really knew much about grades. In fact, I think it kept the pressure down [because] nobody had any clue what the hell the grade they were getting So, ...everybody sort of wandered along and "We'll get what ever we get at the end of the semester." We just know we have to do it, we don't know if it really counts.

4.2.4 Book not consistent with professor's method.

As previously discussed, Woods' method was not strictly duplicated in the textbook. This meant that students had to trust Woods' method and rely primarily on his lectures. Most students trusted Woods and his method and did not question this part of the course. A few students experienced a dilemma because they had never before been asked to use a method that varied from the method presented in the textbook.

S: I guess it's only frustrating when we get to the homework, and since we add the book in, we have to wonder why the book is different with his, and there's just no way of questioning that - just the fact that we're using his [method] and not the book's, and that's about it. And I guess that's a frustration - that we're reading this book, and it's telling us one thing, but we're learning it another. All our lives I guess we've been taught to always - "This is what the book said. It's in the book," and if you ever wanted to prove a difference, you find it in the book.

I: The book is always the authority.

S: Right, and I think that's just because that's the way you've been brought up. When you answer a question in class--see, it says so right here in the book. And now that we're doing it differently--I mean, it's close enough to the book that you can say, "Yes, it's in the book,"--but it's different enough that you get an entirely different answer. And the book explains it differently. I guess that's a frustration--the fact that now we're using the book and now the book's wrong! (laughs) I don't know, maybe I'm fighting for the book. I'm standing up for the book! I don't know.

4.3 Students' relationships with the teaching assistants varies widely.

We found wide variation in students' perceptions of their relationships with TAs.

A few students indicated that they felt they were close to "equals with the TAs" and that the TA functions much like peers do in informal groups.

S: ...the relationship me and like two other students have with her/him is really casual. I mean, yes s/he establishes authority, and yes, people look up to her/him as a really great TA, even people from other classes. But even yesterday we were like joking around about a crossword puzzle! (laughter) It's kind of weird, but I'm not intimidated by her/him at all, and I know s/he's not intimidated by me, of course, I'm a lowly student. But I think it's almost on an equal basis though. I look up to her/him. I know s/he doesn't look up to me. I look up to him, but I'm not afraid to ask him a question at all. I'm not afraid to look stupid in front of her/him...In fact, I'd sooner ask her/him a question about something than some other people in the class and usually people would go to the other people in the class first.

A few students discussed their TAs' tendency to force them to rely upon themselves for answers.

S: ...[My TA will] never give you an answer. S/he'll ask you questions, and then you'll get the answer. And a lot of times s/he'll ask one or two questions and you'll slap your forehead and say, "Oh, I know how to do this!" And I think that's great, because...you don't get into just relying on, just getting an answer. You know, you do learn that a lot of times you know the answer, you just have to think about it a little bit. And I think that's...real important.

Another student related that the TA "asked the questions" and "got the answers" which allowed the student to "learn stuff without really having to search for the answer."

S: ...I like the TA because s/he [laughter] doesn't require that extra work of me in the sense that s/he asks the important questions and really knows what's going on and s/he wants us to know what's going on. So I can learn stuff without having to really, really search for the answer. S/he'll ask the questions that we need to look at and then again in the lab s/he'll ask the questions. S/he'll get answers from a number of people, something that I maybe didn't-wouldn't have come up with, other people will come up with, so I can get the answers from hearing other people.

A few students commented on the difference among the TAs with respect to reviewing homework problems:

S: [It] seems like there is a big disparity between the TA's and the way that they handle the problem sets. Because some of them they will completely go over the problem sets during discussion, show them how to do it. Like the day it is due, or a few day's before it is due. And then some, my TA, will not tell you anything unless you make a special appointment with him and then maybe and he'll kind of look at the problem set and say, "Why don't you think about that." I suppose he doesn't want to spoon feed it to me, but I just want to understand.

One student indicated that those TAs who were unfamiliar with Woods' method brought an outside perspective to the students.

S: ... So there becomes to be more reasons behind what the TA's saying, and they can apply it to things we learned last semester, things we'll learn next semester. And that's something that Professor Woods - I mean, he seems to be unable to do it. But it seems logical to me that he'd be unable to do it because he has his way of doing analytical chemistry, and that's what he's teaching us, so by his theories and his standards, what he's doing is right. I mean, it's chemically right as well, but so there's not that outside knowledge really coming into it.

I: Okay. When you say he seems to be unable to do it, do you mean make the connections between what you did last semester and what you might be doing in the future?

S: No. I mean, I think he could, but I think as far as the class goes, he teaches analytical chemistry, so he uses his theories, what he has learned, and it's all within those parameters of his. Whereas the TA's, you know, this is their first time for a lot of them, working with them, too, so I think they're bringing a lot of other different things and a lot of other different elements into the class that he's not.

A few students felt that their TA was not familiar enough with Woods' method to be very helpful to them.

S1: On the last problem set, my TA didn't even do it. It was like go up there for help, and s/he's like, "I haven't done it yet." [And I thought], "Well aren't you going to do it? You know, you are supposed to help us here." No, no help at all. So. Then s/he graded it. How can you even grade it if you haven't done it? I don't understand it at all.

I: Yeh, that is kind of distressing.

S1: It would be different if s/he hadn't done it and s/he knew how to do it. You know, then s/he could just say this is what to do, and give you a hint or something. S/he couldn't even do it...It is not uncommon. I mean, I am finding that as more of the semester goes on, s/he seems to be doing less and less.

5. Chem 110 Compared to Chem 109 (the other traditional courses).

5.1 Fewer but more difficult topics.

Many students commented that in contrast to 109, 110 covered fewer topics but in greater depth and detail. This required more work and a more thorough understanding of the material but left the students with less material to cover on an exam.

S: It is different. Really different. 109 was probably more general. It's more general. We talked about a whole variety of things in chemistry. Solutions, molality, orbitals and all of that. What we would do is, we would learn more of the theory and do some problems of it. And that was basically it. Whereas 110 it is more specific, more in-depth, it'... It's not as broad as 109. Just more specific. To summarize our topics, we did like, solubility, acid-base, and electro-chemistry. And each of these, we are really going into depth in each of them. Whereas 109 we did a whole variety of stuff...Everything we did everything. So it's like, "Geez how am I going to study for this?" Whereas this semester, in 110 it is like, uh, we did a few things, real generally. And it seems like it is going to be a lot easier to study for this final because just go over the homework and go over your notes. And it shouldn't even take to long to study. But it is a lot more difficult. The actual material is a lot more difficult. But a lot of it is you got to know what you are doing, and you have to do the work. It takes a lot longer. But if you know it you can do it.

5.2 Course is notably more interesting: revived or created interest in chemistry.

One male student's experience in Chem 110 confirmed his desire to major in chemistry:

S: Well, it definitely it reaffirms my desire to go into chemistry. Because I was in sincere doubt after 109. It was just such a mechanical class. I didn't know if since that's all my experience was I was like "Well geez, is this what it's all about?"

Chem 110 helped a female student like chemistry:

I: ...So do you think that you will be changed in any significant way by having taken this course?

S: Oh, geez, I know I have already...I hated chemistry before, and this course kind of makes you like it...I've always loved biology and hated chemistry, that's always been my thing... I enjoy chemistry now. Maybe it's the smaller class, maybe it's more attention that I'm receiving from both the TA and the prof, maybe it's just because I like the prof, but I really like chemistry!

5.3 A deeper understanding.

Many students felt that Chem 110 gave them a deeper understanding of chemistry than any previous chemistry courses.

S: I would say it's definitely worth it [the time spent in Chem 110] because I've learned so much. Maybe not so much that I've learned so much--but its clarified. Everything in my mind that I understand so much more now that I've taken 110. Part of that's due to lab and lecture and stuff that that was...was kind of in the back of my head in 109. Stuff that they kind of told you that went in one ear and went out the other. This time, I mean now thru this...there's just a deeper understanding of the material. And it's definitely-- if your going into chemistry or a highly chemistry related field--its definitely worth the effort.

6. Outcomes experienced

6.1 Improved study habits.

A few students said they had bettered their study habits because of Chem 110:

I: Ahm, has this course changed you in any way?

S3: Ahm, it's increased my study habits, I think they're better. Yeah, I spend a lot of time on it.

I: Has it changed your approach or just the amount of time you spend studying or?

S3: Ah both approach, the intensity, time- all those together.

I: What about the approach? And I kind of led you into that so if it's really true, then tell me.

S3: Um, in high school I always relied upon the fact that if I just did the homework and maybe read the chapter, I could get through. And I never spent any extra time doing anything. And the same for first semester it was, you know, it was "college." [Laughter] Now it's like I guess I kind of enjoy it, sometimes, it depends on the day but I enjoy going, sitting down and rereading a chapter and re-working out a problem that confused me before, but I got the answer but, "Let's go back and look at it and make sure I really understand it."

6.2 Strong friendships.

The students who talked about making good friends in this course felt that this was one of the most positive aspects of this course. In the following quote, the student expressed a sense of belonging from the bonds she had made in Chem 110.

S: It's a lot of fun. You know, we'd go around with these big dumb grins on our face when people introduce us as part of the "chem clique," or whatever. I went out with [my chemistry friend's] roommate, and he's like, yeah, "This is [my friend], part of [the] chem clique." I'm like, "Yeah!," you know, whatever. It's kind of kooky, but it's a lot of fun too.

I: Does that have any affect on your outlook, like for the next four years?

S: It's going to make the next four years a lot more fun, definitely, especially because chemistry, I mean, next semester my schedule's chemistry, biology, physics, and a history class. It's just like, I say this and other people start shuddering, and I'm thinking this is normal. I mean, [one of the people in my group] has the same schedule except for biology, and [another friend] has the same schedule except not the physics, and [another friend] is doing her biochemistry stuff. It's like I can sit there and start talking about something like that, and I know they know what I'm talking about. I'm not speaking a foreign language, and they know what's going on.

6.3 Acquiring an appreciation for the exactitude of scientific experimentation.

A few students described gaining more "in-depth understanding of what's going on" in the world of science through their experiences in Chem 110.

S: ...It's more of an in-depth understanding of what's going on. I don't just say that [a particular reaction] happens because that's just always what has happened. I can kind of see a reason for what's going on. Like I analyze it, I see it on a deeper level of what's happening...I guess in a way I think of a lot of the experiments that we're doing [in lab], it's quantitative and we're expected to get a certain number at the end. And I can see sometimes how difficult it can be to be exact in science. You know sometimes you think "Well how...could a scientist make that mistake? How could they not know that this was a dangerous level of toxin?" Or something like that. And it's...kind of easier for me to see that there are a lot of things that can go wrong when you're doing an experiment and sometimes it's hard to get just the right number. It's hard to get a really exact result sometimes.

6.4 Perceptions of worth.

The issue of whether the volume of work in Chem 110 was worth what students got from the course did not arise in all interviews, and is therefore difficult to quantify. Two responses are presented below.

One student felt more time was spent on the course than was justified by the outcomes. This was in part due to a dislike for chemistry for having to "learn things just to know them."

S: ...it's been really, really, really hard you know, I purposely took a light course load this semester because I knew this class was gonna be hard and that it was gonna involve a lot of time. And even with that it's been really hard.

I: Ahm, so if a friend were to ask you if it was worth all the time you spent on it, what would you say?

S1: No. [Laughter]

I: Would you expand upon that? [Laughter]

S1: Ahm, I don't feel that for the amount of time that I've spent working on this, I've learned as much as I should have.

I: Can you tell me more about why you don't think [the sciences] might be right for you? You talked [earlier] about [switching to the Humanities].

S1: Ahm [Pause] well I'm a lot more interested in biology, I'm a lot more interested in- I think I'm more interested in things that I don't know yet or that aren't known yet. You know, things that I can find out. And in chemistry, I mean OK there's a lot I don't know but there are things that people know and they're trying to teach me and it's more like something I have to learn instead of something that I'm going to do. So I don't want to learn things just to know them even though I know I have to do that before I can learn anything else, you know.

I: Yes. What does that mean for you? To learn something that you just learn just cuz you have to know it.

S1: It's like getting through it until I can move on to something else, that's what this class is like.

Some students said that the hard work they had expended in this course had been worth it. The following student did not necessarily think the chemistry concepts would be used again, but the student valued learning the analytical process.

S2:...for lecture, it's good to understand the stuff, but I don't how much of it I will ever use again. Long drawn out equations

I: what do you think about that, whether or not you are going to use?

S2: It doesn't really bother me, because I know that has happened in some other classes.

I: Calculus?

S2: Yes, exactly, Calculus. But I think it is the method of thought and that you have to learn to deal with and I am going to use that again in analysis. Although I might never actually work trying to find a chemical oxygen demand lab, calculations and follow thorough.

I: Can you tell me more about the method that you are talking about that you have learned?

S1: To be very very picky.

S2: Yes, very very picky. The importance of quantitative analysis as opposed to qualitative and it teaches you a lot of patience.

Woods Lecture: From the TAs' Points of View

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Woods Lecture: From the TAs' Points of View

Note: Due to time constraints, the researchers achieved less closure in analyzing the teaching assistant interviews than in the student interviews.

1. TA Goals.

In general, the Woods TAs sought to get students excited and interested in the chemistry material as well as the basic goal of assisting the students in learning chemistry. These goals were presented by one TA as follows:

> R: At first I...wanted to get everybody excited about [Chem 110] but as you go on you realize that you aren't going to get everybody excited about it and that's how [TA goals for students] change. You just realize that you can't get everybody excited about it. So you just change your mind set about how you teach them what they need to know then instead of showing them every minute detail of extra stuff. I like to show where things came from and if I find that students are...closing their eyes in discussion or whatever, you have to kind of change the discussion a little bit because of that.
>
> I: *...To what extent have your goals been met, and in what ways do you know that these goals have been met or not met?*
>
> R: ...There's one particular student that at the beginning of the semester got a pretty good grade on the exam--he got maybe a B or something--and he didn't really turn in all of the homework, you know, like in the beginning before the first exam. Then all of a sudden I saw this change, where every homework he'd start coming to my office hours and getting help and stuff, and that is very rewarding, and he did much better on the second exam, and that's rewarding inside, cause you're just like, you know, this can happen, and this person is interested in this now, and that makes you feel really, really good, to have people interested... At the same time, you see people fall off a little bit during the semester too, and that's a little discouraging, but for the most part I've seen people get more interested in stuff as it goes on, and they try a little bit harder.

2. TA Perceptions of their Roles

2.1 Preparation for TAship Is a Concern

The TA quoted below felt unprepared for his/her role as teaching assistant. S/he indicated that the preparation for being a TA in Woods' class was so integrated with Woods' method of solving equilibrium problems that it was not possible to separate preparation for the TAship from comprehension of Woods' method.

R: Yeah, I sort of feel like I was unprepared. I feel like I was unprepared and it can be frustrating at times because I don't know this method off the top of my head. Because it's new to me. But I can get around that because I like the method well enough that I'm glad I learned it. I'm trying to be diplomatic. (both laugh) [I] do feel unprepared sometimes because I don't know every aspect of this new technique in and out.

This same TA commented further on the need for TAs to learn Woods' approach to analytic chemistry in order to help the students, and stated that s/he found this new method interesting and effective.

R: ...Dr. Woods teaches a totally different method of solving equilibrium problems, that I find very interesting and I think it's an effective... At the same time, as a TA, when you're learning it along with the students it's a little bit more difficult. I liked it a lot. I learned a lot this semester. but at the same time I had never seen these techniques before. So, you had to keep on your toes, you always had to keep up with the lectures and you know, do the homework on your own first before...it comes out. You really need to do the homework, because, once students come to you and ask you questions, you have to know how to solve it. The way he teaches equilibrium theory is not the way that I was taught when I was an undergraduate. He has a different technique--a very nice one actually.

A different TA, who had no experience teaching prior to last fall felt frustration at times due to not understanding Woods' method of analytical chemistry.

R: I have no previous teaching experience, and I had no training since the fall. I don't know [The idea is,] "You know the stuff, so why not teach it, right?" ... I feel more frustration over it now since I don't really know the lecture quite that well. I feel bad about that, but I guess I'm not doing anything about it. But yeah, so I get frustrated ... I don't think it's that we can't teach analytic because, I mean, instrumentation and stuff like that... but if you [teach for] Dr. Woods, unless you're [specializing in this area], forget it, because we don't need to know or care to know all the equations for all these multiple quantity equilibrium problems and stuff.

I: *So he takes a different approach from -*

R: Everyone else in the world, yeah.

The TA quoted next felt there is a need for more preparation in conducting the discussion sections. This TA also expressed that s/he felt like one of the students learning the material (or method) at the same time they were.

R: Well, it's getting better, you know. Many things that one prepares for are things that are constant throughout the whole semester, so I didn't feel as behind in my preparation the second half of the semester as I did the first half of the semester... the lab stuff started to come after awhile--but the classroom stuff, a lot of it was still very new, and I kind of wish that I had had more preparation for that.

Another TA expressed a desire for more preparation as follows:

R: If he'd teach us the course before we teach it. Other than that, I mean, he's a good professor. His lectures help [us] try and give them an answer, and I think he answers questions well...

Yet a different TA suggested preparation could be improved if they received notes ahead of time.

R: I think maybe notes ahead of time to know what we're going to do ahead of time. Just a little more information so I could look it over first. Whereas I'm getting notes the same time as the students are. If I'm lucky I can look at it before the students do. These are pretty motivated students, and more often than not, they've looked at it before I have.

One TA indicated an interest in more frequent TA-faculty meetings.

R: I think maybe if he told us more in advance what he's going to be doing for the rest of the semester. You know, he does tell us a certain amount when we're in meetings, but the meetings are kind of sporadic, and I think they don't get specific enough. It would be nice if we had a little more idea of where he's going, maybe had the problem sets and/or answers more in advance. Other than that, you know - I mean, his teaching is fine. He seems to do really well.

I: *When do you tend to have meetings?*

R: Well, it depends. When he feels we need to have a meeting, you know, but it's usually once every two or three weeks. It's been awhile since we had our last one. We generally have them after lecture on some days. Sometimes he doesn't even tell us that in advance, he'll make an announcement in class at 11:00, you know, that he wants to see the TAs after class... I don't really like that, because sometimes you actually have things planned... But usually he'll come to lab the [day before and] and say, "Can we have a meeting on Friday?" and if we can't, schedule for Monday instead.

Two TAs who already had taught this same basic material presented in Chem 110 felt much more confident about their preparation.

R: I taught basically the same class last semester. It was 223. And so I felt more prepared. Because I had seen the majority of the labs before, I knew exactly what was going to go wrong, what they were going to have problems with. So in that sense I felt, I felt more prepared. So I think my preparation was...

I: *The same case with you?*

R2: Yep. I taught this class last semester so..it was no big deal. [It was] different having freshman though.

Another TA explained that the authority/source of advice role expected of the TA was difficult to play due to lack of preparation.

R: I think [having a TA] gives [students] a different perspective on how to approach problems, `cause we all come from different places, you know. [Two of us are inorganic chemists and each] comes from a different area of inorganic, and the three analytical people all work in different groups and kind of work in different areas of analytical, so their brains are in a different area of chemistry. So we each think of different things first than the others do, [and focus on particular projects in our specialty areas].

I: What does that do for you as a TA, that your project is related to your background?

R: It makes me feel more confident (laughs). Confident and I think I have gained more respect [from the students] in the last week and a half doing this stuff than I did all semester because most of the semester they had the book and I had the book, so we all had the same information. Whereas now I feel like I have more information than they do so I can be more of a leader than just an organizer, I guess.

I: Does that make a difference with the students, that they can look to you as a leader? What do you think?

R: Yeah, I think they see me as a - I don't want to say authority, but a fount of knowledge, or whatever. You know, somebody that they could come to and ask questions about, other than, "Where is this reagent?" and to help lead them on the projects as opposed to--[answering] the biggest question we ever get: "Is this the right color?"

I: Why do you think students do that?

R: I think they just want confirmation they're doing it the correct way, but since we've never seen it before either. we don't get the chance to do all the labs ahead of time. of course, we see about five of [the labs] done right we'll know, but some of them you don't. With some of the labs it's a judgment call, and students can make the judgement just as well as we can. It's just that they don't have the confidence to make that judgment call, and we, given the position that we're in, have to have the confidence.

I: ...do you think the TA's role is best to be like the authority?

R: I don't know if I like the word "authority," but I would like to be able to--what's the word? I mean, organizing, obviously I'm going to have to organize it. I'm going to have to do the piddley things you have to do in order to keep the group together. But I'd like to be able to be the person can come up to and ask advice from. Not just ask for the answer to the question, but ask about approaches or run things by me so I can evaluate them and maybe find the holes. So what would you call that kind of person?

2.2 The TA plays multiple roles

One TA emphasized that TAs viewed themselves as playing a role in counseling students on their course selection and acting as a mediator between the students and the professor.

R: I think I talked about being a facilitator, or kind of between the teacher and the students... I think that actually if nothing else it has probably expanded my role as the semester goes on. Now that it's the end of the semester, they're talking about a lot of different things with finals coming up...

I: What sorts of things have come up.

R: Well, they're talking about their next semester classes-- generally they're talking about taking organic chemistry now, so I'm going through a lot of professors and finding out things about the organic class because they come to me and ask me questions about "What should I sign up for?" Those kind of things, which aren't exactly class related, but those are the -

I: Assisting them.

R: Yeah, in their overall journey.

I: Anything else....

R: Well, they always ask me when the exams are (laughs). I'll say, "Well, I'll try to bug him about it some more." Then I'll tell him to maybe set an earlier time than this time. I do transmit their concerns. [For example] when they thought their first test was too long, I mentioned it to him, and he said, "Okay, I'll try to make the next one not quite as long."

3. TA Teaching Strategies

3.1 To Give or Not to Give the "Right" Answer to the Students

The following TA wrestled with whether to provide answers for the students. This TA was aware of the need for students to struggle in the learning process. This TA found that the students developed more independent problem-solving ability over the course of the semester.

R: Well, I guess they see the process that I go through in order to figure it out and...[that] sometimes I utilize them in order to help me figure out [the homework]. So sometimes it can be good because...I'm asking them questions, and they're thinking it through as well instead of just telling them what the answer is. Which I hope I don't really do. But I end up doing it after awhile anyway. But then we go down a lot of wrong avenues and there's probably a little bit of time wasted so there's both positives and negatives, I guess. And the fact that I look a little unprepared, which is not always good...

R: ...Well, there's always a few stragglers that you've got to really pull up with you and you end up giving them more answers than you would somebody who's thinking about it really well in order for them just to finish the project. And you start working on them, on little basic stuff, instead of working on the fine points that you would prefer to work on.

R: ... I think I let them do more of the figuring out of things, because I know they're more capable of doing it from the beginning of the semester to the end of the semester. They are more able to come up with answers on their own. So I think I've started [to] realize that. So part of it was that they were getting better. Part of it was because I was able to let them--you concede to them that some of them can figure it out just as easily as I can tell them. I think, I hope, that I'm letting them come up with their own answers. At least that's something that I've been doing more of, so I've tried to do that.

Another TA encouraged students to figure things out for themselves by generally asking them questions.

...I like to ask questions. Rather than give them the answer right out. [It] depends on of course the nature of the question. If I can tell that a student is very upset with something or very frustrated, then at that time sometimes I'll step in and say "This is what it is." But for the most, [I'll] ask them a question. Have them try to figure it out themselves.

Another TA viewed his/her role as a "lab teacher" and a source of homework problem answers.

R: At the beginning of the semester, I guess you obviously just see yourself as kind of a secondary teacher or a helper teacher...that you get the knowledge from the professor. And then I kind of pick up the pieces and try and shove them back in.

I: How has that changed, or has it.

R: Well, I tend to see myself as the lab teacher, where I make sure everything goes okay in lab and they get their final answers out and they get okay results so they can get a good lab grade. I don't like Doctor Woods' rule, the discussion rule, cause I don't know any of it...

I: So where do you think students go if they have trouble with discussion or trouble with the lecture material.

R: Well, luckily [the] professor gave us an answer key, so they ask me a question and I say, "I'll be back in a little bit," look in the answer key, go back and give it to them...

3.2 Discussion Sections

The TAs used discussion section time address lab issues and to answer questions about homework, lecture or lab. Many also employed quizzes in order to help students improve their knowledge of analytical chemistry, although at least one did not give quizzes.

I: How did you approach the quizzes, if people we're all doing different parts of the lab?

R1: I didn't have quizzes.

R2: I did, and I usually would quiz over labs that were done the previous week so I was sure that everybody had gotten to them. That's the way I approached that. I tried to [have a goal for quizzing students]. On the quiz I tried to emphasize the things that I felt were important in each of the labs. I guess that was one way of evaluating whether they understood what was going on... Sometimes I would give them some sample data and say, "What would you calculate for your answer?" Other times it would be more conceptual. So it just depended on...

I: Why did you decide not to have quizzes.

R1: I never even thought about it. It wasn't a decision. I just never thought of even having them so...

A second TA stated that for his discussion section there is an informal relationship between quizzes and attendance.

R: ...I told them that mine [discussions] were optional except when I had quizzes. I wouldn't give a quiz every week but on the weeks that I did I'd still get probably three quarters of my class there. So there were people that would not attend at all...

I: So what did you do in discussion?

R: We talked about the labs a lot. And homework. Generally. Except at the beginning of the year in discussion it was giving them a lot of background about the labs.

Other TAs also explained that they used quizzes as a learning tool. For example, one sought to design quizzes that really provide students new understanding of the material:

R: ...Or sometimes I'll even hand out a quiz paper and I'll put the quiz topics down. I gave two quizzes on lab material, and one quiz on lecture material. The quiz I gave on lecture materials I gave because it was before an exam, and I wanted them to start thinking. I was hoping to teach them something in the quiz instead of really testing what they knew. I was more concerned with--I tried to write it so that when they did it they'd say, "Oh, that's how you do that." I don't know if I accomplished that very well, but that's what my intent was.

One TA discussed a need for more time spent in discussion section.

R: I wish I had more time with the students in discussion. Because I end up spending almost all the time on lab stuff, and even the quizzes end up being on lab stuff. There are so many fine points they should come away from an analytical class knowing--techniques and thought processes you need in order to do the analytical quantitative analysis that... we expect them to be able to do, that aren't really covered in lecture or are just skimmed over or you just really can't learn in lecture situation. You have to actually do the stuff. So there's so many things that I think are important for them to learn from lab that it would be really nice if we could spend one day a week on lab stuff and one day a week on the lecture stuff so that there's--cause I do feel like I'm giving the lecture stuff a little bit short shrift, or whatever.

Another noticed a shift in discussion section focus as the semester proceeded from lab to lecture topics.

R: at the beginning of the year we were stuck teaching the labs more than the class. Which was fine because they were getting as much as they could out of the class already. We didn't really need to do anything with that. But now toward this time of the year we can spend more time with them on class work and stuff. So it's changed a little bit in that we don't have to lecture so much about the labs in our discussion groups. We can talk about the class more.

4. TA Perceptions of Course Process and Structure

4.1 Need for a Syllabus

One TA noted that students need a structure in which to function effectively in Professor Woods' class.

R: I think they have adjusted to a certain extent. I think they would still prefer to have a syllabus and have more of a book in order to look at things, because that's the way they've always done things from the beginning...because they're organizing people by nature. If they've got tests in other classes, they want to know when they're going to have to start studying.

I: *Are there positive and negative affects to not having a syllabus?*

R: Well, I think there might be some negative affects in the sense that they don't know exactly where the next step is. They keep asking when we're going to start electrochemistry because we had had labs on it... They say, "When are we going to have electrochemistry so I can learn how to do these labs, these calculations, or whatever?" I just say, "I don't know."

Two other TAs indicated that they would like the professor to add more structure to the course by using a syllabus.

R: Without a syllabus, at the beginning of the year, as TAs we were also unsure of what material he was going to cover. So now at the end of the year, when we find out that he hasn't done any spectroscopy or separations, the students wouldn't know whether they were exposed to something or not.

R: Right. As TAs, it's like, "I think they should have had at least a couple days of lecture of this." To give them an idea of what's... [If someone asked them] "Did you get as much out of this as you think you possibly could?" the [students] wouldn't know.

R2: ... in the course of my teaching, when they've had a question I've said, "When we get to that in lecture, then it will make more sense," or "When Dr. Woods covers this then you'll see a little more clearly." And come to find out he's not going to get to it so... Bad assumption on my part.... Going through the class now with him, seeing how he teaches it and whatnot, I'd be better prepared if I were his TA the next semester. But without a syllabus the TAs are kind of in the dark at the beginning of the semester--for most of the semester. Also, a syllabus for the TAs is exactly, "These are the things I plan on covering." Sitting down and talking with us at the beginning of the semester would have helped.

While the TAs conveyed that the course structure is not obvious to them ahead of time, they also explained that they enjoy TAing for this course and appreciate the professor's patience and listening skills. One presented this perspective as follows:

R: ...I really like the way that he teaches equilibrium theory. That's influenced me a great deal. And he's very patient, and I really admire that a great deal. You'd always like to be as patient as possible, so those are the two things I can think of off the top of my head that have influenced me... He's very good about listening to the students' concerns--whether they understand. [For example] we started the electrochemistry section, and he wanted to know if the students were understanding the parallels that he was drawing between the electrochemistry and the acid-base stuff, and I said that I thought that they really liked the fact that we weren't completely jumping.

4.2 Better Pacing to Avoid End-of-Semester Rush

One TA felt that the pace of the labs was extremely fast during the last part of the semester.

R: ...I felt like we raced through the semester as far as the labs go, and I wouldn't mind knowing if [the students] felt that way too. Would they have liked to have taken a slower pace with the labs and had the chance to learn a little bit more what the labs have to offer? ... As a TA I would have liked to have moved a little bit slower so that I could have emphasized certain points. But we went pretty fast through the labs. I'm just wondering how they felt going that quickly through labs.

Another TA explained that s/he felt compelled to rush to get the students through the semester.

R: No, I think the students' goals are pretty much the same [as mine], although near the end of semester you start thinking, "I've just got to get them through the class." You become somewhat less idealized.

4.3 Little Correlation between Lab and Lecture

One TA described frustration over lack of discussion section time, and associated students' need for more time in discussion section with the lack of connection between lab and lecture.

R: It's just--we go in and we do the labs and we try and give them as much information as we possible can in the time that we have. It's gone pretty much the same the entire semester. I think that my students are pretty good at lab for the most part. ...The one thing I know that people have mentioned throughout this entire semester is the fact that there's not a whole lot of connection between [lab and lecture]. ...That's a little frustrating, because you have one discussion period a week. As a TA you have to decide what you're going to talk about that day. In general, I come in and ask if they have any questions. And if there's a homework set due, there's certainly going to be questions on homework, and that could take up an entire discussion period. So I usually prepare something to talk about, but then the questions usually take the entire time. So I don't get around to talking about some of the details of the labs that I would like to emphasize, and they may not have been covered in class, so that's a little bit discouraging, but I think that's just sort of the way it is when you have a lecture or lab situation. I think that happens. I mean, it happened when I was an undergraduate too. So I try as much as possible to cover both needs, the lab and the lecture, but that's kind of hard sometimes.

Another TA felt that lab and lecture were more connected at the end of the semester, not by plan but because of luck.

R: The correlation between lab is just luck because the ending labs happen to be electrochemistry-oriented, and the end of the semester did too...

Yet another TA conveyed that the lab and lecture fail to correlate.

R: ...They're doing the labs that they should be learning about in the classroom. Normally you have your classroom that kind of runs parallel with your labs. But the labs is-- we have learned chromatography and we are learning spectrometry, but they can't really learn them, they just kind of use them. They give results either in the lab book or I tell them how to plug and chug into the equations to get out some final answer, which probably means absolutely nothing to them cause they don't know how they got there.

I: And you know that by talking to them?

R: Well, both. They've told me that, and just being in their shoes--if I hadn't ever learned anything about any of it and all of a sudden I had to do it, I wouldn't know anything about it.

I: That's interesting. So in your experience it has pretty much always been parallel, that the lab and lecture go hand in hand?

R: Yeah, at least somewhat. Sometimes your labs get ahead of your discussion or your discussion gets ahead of your lab or something, but at least your only - at some point in the semester you're going to talk about what you've done in lab.

I: Do you feel like that would be entirely possible with this subject material, or what do you think.

R: Oh, yeah.

Two other TAs also have strong views about the correlation between lab and lecture.

R2: I still feel very strongly that [they] might as well treat them [lab and lecture] as two different classes. There's no correlation.

R1: At the beginning of the year we did a lab specifically with weak acids. Half-way through the semester, they finally learned about weak acids and what the experiments look like. And then they're all like "Oh! Oh, that's what that lab means!" It wasn't until two months later that they finally figured out what they had done in lab. And now we're doing another weak acid lab, and it's trivial. It's just a joke. They understand it completely. It's just nothing. So I think it should follow--the lab should follow the lecture more.

Two TAs postulated that the fact that each student may be doing a different lab during any given lab session contributes to a sense of disconnection between lab and lecture. This fact also requires extra effort from the TAs, who have to juggle many lab procedures at one time. In the interview fragment below, these TAs discussed the difficulty of balancing the students' goals with their own goals for lab. One also noted that when this students are all working at different things, it's harder to work with them and help them understand what they are doing.

R2: This semester was really wild. So many labs going on at once... I have fourteen different students and there might be five or six different labs going on at one time. So it's always hard to tell if everybody got out of it what they should have gotten out of it.

R: Yeah. I don't know if my goals have changed but I've found as the semester has progressed it's harder to do all that I thought maybe I could do or wanted to do... I guess trying to pay attention to every single experiment that's going on, it gets really, really tough so I focus on maybe one experiment that's going on. I try to go around to those people that are doing it or... I guess maybe it's more I turn to problem solving towards the end of the semester. Or equipment is breaking more or whatever. So it's more trouble-shooting and problem solving at the end of the semester than going around and asking them how things are going.

I: *Do you think it's optimal? That students can work at their own pace, and they end up working on maybe five different labs?*

R2: I think it's good, because some students just work at a different pace than others. I have one kid who works very fast and he gets 100% on every lab. And people like working with him too as a partner because he just gets it done and is gone after two hours. And then there are the other people who are there [until] 5:30 and class is over at 5:25 and "Hey could you start cleaning up now? Because it's time to go. Ten minutes ago." I think it's good that they work at their own pace as long as when the lab first started you've told everybody how it goes so that when they come back to it and they have to actually start it they're ready to go.

R: Well I was going to say, one thing. I think there is a little bit of a lack of understanding about what the lab was all about sometimes. They just do it. Get a good grade on it. But they don't know what they did. And it's hard sometimes to get--when they're all working at different things--to get them together and say "OK. Here's what was important about that lab." You can tell them beforehand, but until they've done it, it doesn't make much sense. Then after that, they're all working on something else anyway.

4.4 Homework strongly related to doing well on exams

Most TAs indicated that students felt doing the homework was essential for doing well on the exams.

I: *How well do you think that the level of understanding correlates with the grade they're getting, like you say, half the class gets an A?*

R: I think people who I call my better students are getting A's, and people who aren't my better students aren't getting A's. The best correlation is between the people who do the homework and the people who don't do the homework.

I: Some people don't do the homework.

R: Yeah. Just basically the test is the homework, you know. If it's on the homework then he's giving it to you on the test, so those who did the homework are the good students, are rewarded, and those who blow it off get blown off on the test.

5. Curricular Content

5.1 Chem 109 an inadequate preparation for Chem 110

In the following interview excerpt, two TAs commented that they felt some students were not quite prepared for Chem 110.

R: ...because..I don't think they were prepared for this class. To tell you the truth.

I: In what way?

R: I think someone who takes 103 and 104 and then takes 221 is better prepared than the students who take 109 and 110. They just get more information... out of those two classes than they do in 109--because they're coming in and asking me questions that I thought they should have known. A girl was asking me yesterday what normality was. And I [thought], "If you don't know that by now, something is wrong." I can say that.

R2: ... There's just a few things that again it goes back to also not having as much chemistry to start out with as the 221 students. There's just a little bit of a lack of understanding of some things and then not enough exposure to others.

Another TA discussed how s/he believes students are missing essential coverage of concepts in Woods' analytical chemistry course, explaining that students "know too much about too little."

R: I actually requested this class cause I enjoyed my analytic class. The analytic class I had was instrumentation and a lot more ideas and concepts of how things work and this class has just been all multi-component equilibrium and lots of equations. I'm sure it's all fine and dandy, but it seems like they need to learn a lot of other things more so then they need to learn solubility and acid-base...

I: So, do you think that happened - do you kind of feel like it's too theoretical?

R: No, it's they know too much about too little, when they should know, I think, a little bit about a lot at this point. If they ever want to become the world's greatest solubility chemist then they can learn all they want about that later.

I: So then you're frustrated with the content, then, just in the class.

R: Yeah.

Similarly, the two TAs quoted below felt that because of the in-depth coverage of only a few topics, students will be missing essential aspects of analytical chemistry.

R2: My opinion is they haven't been exposed to enough. I guess there's two different philosophies. One is to cover a few topics, but real in-depth. The other one would be to cover more topics less in depth on each one. This one we've covered very, very few topics but very, very in-depth. And if this is going to be their only analytical class, before they get to their upper division, I think they've been cheated out of a couple of areas that I feel are important.

I: *Which areas?*

R2: Umm...

R: Spectroscopy.

R2: They haven't covered anything about spectroscopy which is a major, major part of analytical chemistry. And we haven't covered separations at all, which is another important part.

I: Hm. So, what sort of consequences will there be for the students. I mean looking long term, what...

R2: Well when they get to their upper division classes, there will be a certain amount of knowledge that is presupposed. And they will just have to work harder. They may be behind a little bit when they get to those topics.

I: Mmhm. What's your feeling about how much they've learned?

R: Umm, pretty much what [the other TA] said... Again it goes back to also not having as much chemistry to start out with as the 221 students and there's... just a little bit of a lack of understanding of some things and then, not enough exposure to others.

6. TA Perceptions of Students

6.1 Different Patterns of Adjustment in Dealing with the Challenges of Chem 110

Several TAs discussed different patterns of adjustment in dealing with the challenges and frustrations of Chem 110. One TA conveyed the idea that when the frustration level gets very high, "it's up to the students": students make the choice to either give up or work harder. The TA quoted below felt that some may have chosen to give up because of personality, "They either decide to do it, or decide not to do it."

R: I'm sort of learning this as I go along too. But how have I adjusted? I just try and understand the problems better, go to lecture, take really good notes, and try and understand things. That's how I adjust, I don't know--see, there's lots of different personalities in my class, so it's hard to say. I think some people give up. I think that that happens, [to] anybody. I've seen that happen before with my own classmates. You get to a point where you get very frustrated, and some people give up... Or just say, "It doesn't matter anymore," whatever. But I think some people then just face it head on and just really try and understand things more and work harder. I see two different things happening, so it's hard to [measure] because there's different people that are frustrated at different times ...Some people are just, they're set, they can do this stuff, and some people it takes a little bit more work, so it's frustrating because you look at people who get it a little bit more quickly than you get it. I've been in that situation too as a student. It can be frustrating and you have two decisions. You can seek help and try harder, or you can just let it go. Some students adjust differently I think.

I: Yeah, it becomes a matter of choice.

R: Yeah, it is. I think it's a matter of choice, because I think that every student in this class definitely has the ability to do very good work and you have to make a decision to want to do that work... It's up to them [the students]. Definitely, I think it's up to them. And for the most part, I think all the students do meet that challenge. They try to meet you half way, and that's important cause if they don't then it's just one person pulling for you, and it's kind of hard. That's how they adjust, I think. They either decide to do it, or decide not to do it.

Another TA described the "stragglers" in his/her class and indicated that they were less engaged in and committed to the material in the lab project. S/he proceeded to relate this lack of engagement to competing demands and obligations in their lives and their ability to cope with these other demands.

I: What do you think the factors are in them being stragglers?

R: I think they just haven't put the thought into it that much... We're doing a final lab project... Some of them really have thought about it and have thought about all the contingencies, all the things that might interfere, and other people are just kind of coming to class and saying, "Well, what should I do?" The ones who have thought about everything are really getting a good experience out of it, and they're learning that kind of stuff. The ones who just come up to me and ask me real basic questions that I know they could figure out on their own, clearly aren't going to get as much out of it. And I think a lot of it's the time spent on it and how much they care. A lot of students just really have a lot of other things to worry about and can't handle their classes as well as maybe some of their other classmates can. And so they haven't had time to think about it.

I: Yeah, I was wondering if you had noticed any factors or any reasons why particular students seem to put less thought into it.

R: I think it's how well they deal with their other obligations in life. I think the students that are there are fairly motivated. There's maybe one or two that I wouldn't call motivated people. But it's just they've got all these demands on their time and some of them can deal with it better than others. Some of them might have more personal problems or something. So the percent of brain space that they've got for this class is different. It's clearly some students who the rest of their classes are a breeze, so they can afford to spend some more time on this.

A TA noted that most students have learned to "go through the system," and had thereby lowered the frustration level many experienced at the beginning. The TA also suggested that the student frustration level is tied to anxiety over the exams, rather than being linked to learning the course material.

R: [Students have adjusted] fairly well. I mean, they know what's important now. They know how to do it, to go through the system, to go through 110. I think that they've adjusted pretty well, and whatever they've been frustrated with in the past they've just sort of dealt with. And they're finding, that they can do it now, that it's not that bad, as bad as they may have once thought. They've learned the techniques, and now they feel like they might have the tools to ...

I: So adapting or learning some of the techniques and learning to work with the tools is part of it. Is that all, or has there been one thing that's kind of helped them or hindered them in this adjustment period?

R: Um, I'm not exactly sure. They go through times when the frustration level is a little bit higher, and then there's times when the frustration level is way down again, so it's hard to say. Like, right now the frustration level is a little bit more down. I think it comes with waves of midterms. So I think that sort of sets what the frustration level is going to be in a class. As far as them adjusting to it, I don't know.

6.2 Dependence on Instructor Authority

One TA observed that the students regularly attend and pay attention to lectures. As one TA indicated, the students found that the only source of the information was Woods, so they had to be there at class.

R: ... They would at least like to know some things ahead of time. I think they're getting used to the fact that they aren't going to know a semester in advance. Almost everybody comes to class almost every day--unlike many of the other classes that I've taught, because they know that the class time is very valuable, and they are attentive. I noticed a lot of people who are actually really paying attention in this class, and that's true. Almost everybody pays a lot of attention in class because they know that's the only source of information, besides their peers. Which is, I believe, why they have to check [on things with each other]. Just in case there might be an error in their notes, they check notes with their classmates.

One TA indicated that the most common question the students asked was, "What color is this [solution]?" They also indicated that the students displayed a lack of confidence in their own judgement and related this to the emphasis on accuracy in the lab and student concern about grades.

R: ...Because they'll ask me, "What are the units on this?" I'll say, "Well, what were the units that you were using?" They'll go, "I don't know." I'll say, "Well, why don't you go back in your book and find out what units you were using to begin with because you know they're the same units." They actually come up and tell me what the units were and I'm saying, "Sooo?" He goes, "Sooo, that would be the units." You're like, "Why did you ask me this question? You know that you have all the tools right there to answer that." So sometimes I tell them or I'll say, "I don't even know why I'm here. You guys could figure this out all by yourself." They err by asking me too many questions because they're so concerned or they're lazy - sometimes a combination of the two.

I: Is that across the board, or do you notice one particular group of students that does that?

R: I don't know. Each student's different. Some of the ones are definitely lazy and ask me questions like that. The other ones are just really uptight about [it]. Some of them are just like, "Are you sure this is right? I don't want to get the wrong [answer] because they are graded on their numbers." If it is wrong, if they go past the endpoint where the color changes correctly, they get a poorer answer, so you can't really blame them too much for asking that question. So I can at least see why they do it ...I think they just want confirmation they're doing it the correct way. But since we've never seen it before either, because we don't get the chance to do all the labs ahead of time too - of course, after we see about five [labs] done right we'll know, but some of them you don't. Some of them it's a judgment call, and they can make the judgment just as well as we can, it's just that they don't have the confidence to make that judgment call, and we, given the position that we're in, *have* to have the confidence.

6.3 Outcomes of the Independent "Unknown" Lab Projects

6.3.1 Fosters group and cross-group student interaction

Several outcomes of the independent "unknown" lab project were noted by the TAs. One` outcome was that the students utilized many of the resources presented to them during the course including themselves, friends, groups, the text and the TAs. One TA found that even the stragglers were brought along and learned better with the independent project.

R: I think it [research project] makes them feel important. I think it makes them feel like they're emulating what a scientist does and they've actually learned something over the semester, `cause they are drawing on a lot of the techniques that they've been learning. We're trying to encourage that, draw on some of the techniques that they used all during class, and they can sit back and go, "Wow, maybe I did learn something!" In addition they're using their book a lot, and they feel good about the fact that they're using the book (laughs) because it's got a lot of references to a lot of different techniques that they can use.

I: Okay, I can see this is where a lot of the students would sort of fall out. I mean, the students that you say have been sort of stragglers, this must be pretty difficult for them.

R: Actually, there's a group of students that really, they're kind of behind. One of them's struggling to come up and is really catching up and is making a good effort, and the other one's really kind of straggling along. I was afraid that they would just have a really hard time with this. So they had this problem and they went to the library and I don't know how they did it, but they found a perfect reference that told them exactly how to do everything. It was amazing. I had to show it to all the other TAs. It was perfect! All they did was do a little bit of research, and they found a perfect way to do it, and I saw the results today. It was perfect results, so the people who I thought least would be able to handle this situation actually handled it better, and it could be just that it's a different thing and they're better at doing the associative process, better than we expected.

A TA noted that the independent project brought many students together into groups. The groups, formed informally, showed few signs of competition, fostered division of labor, and seemed to have generated a support network that supersedes gender boundaries.

R: They seem pretty genial. They're doing these projects now and they really talk among themselves a lot. They're doing different specific projects, but a lot of people are gleaning a lot of information from other groups and how they go about things. I think they work together really well and I'm proud to say that I have three male/female groups going together this time...I didn't assign groups or anything, they just came together, so I was pleased about that. There doesn't seem to be a whole lot of competition, they seem to be working together pretty well. They've been working together, not just within the lab section, but across the lab and across the hall. You know, people are doing kind of the same things. We've got a lot of other TAs helping other people's students because generally one TA gets really good at a specific problem, and each section has one pair that's doing that problem.

6.3.2 Fosters student independence: a hands-on experience with the research process used by scientists

Several TAs conveyed that this "research opportunity" afforded students a chance to make their own decisions and experience the research process of scientists.

R: ...They don't seem to be as frustrated with the independent projects as I've seen in the past. I've done independent projects before, but the ones I've done before were a little bit more difficult than these, so that could be why. They seem to be pretty independent in thinking about them and pursuing how to solve them...

One TA explained that the unknown labs help students act like "scientists," and "learn the research process."

I: What sort of problem is it?

R: Well, they're just given - actually, what we did is we took a list of chemicals that had been combined about 10 years ago when Professor Woods taught the class last. We found the list of the things that they combined, the two chemicals that they combined, and they had to determine the percent of each compound in that mixture. So we knew that there was an answer somewhere. But it kind of helped us to not know the answer, because we figured even when they were going down dead ends that they were learning something from it. And I found that that was pretty much the case, that sometimes they learned more from going down the wrong alleys...But I think it's been a really good learning experience for people just to be able to think through things because the students do come up with ideas. Some of them are great. Some of them are things we never thought of ourselves, and I'm afraid that if we had some preconceived answer we would shoot it down before they even fully conceptualized it. Some of the problems are really not well thought out, and we can ask them, "What do you think you're going to get out of this?" And they'll tell us. Usually they can come up with the problems themselves but I think they like the give and take with the TA working through the thing together ...So I feel I can help them a lot on that...I try to call it "research" instead of "doing a lab," because that is really what they're doing. They're not following a prescribed lab, they're researching, and I think they get a kick out of that.

As the following excerpt shows, while at least one TA felt the unknown lab project was easy and thus "no big deal" for the students, most also believed that the final project provided students an enjoyable challenge and sense of independence.

R2: They're ready for the semester to end also but right now we're doing some independent projects and 99% of my students seem to enjoy them. If they can still enjoy Chemistry I guess that meets one of my goals [which] is to make them, help them to see why I enjoy Chemistry and that it can be fun...

I: So tell me more about the unknown labs and how the students are reacting to those.

R2: My students are done with.

R: It was no big deal. It was too easy.

I: *Really?*

R: Yeah. Especially the weak acid. It took a little while for them to figure it out, but once they figured it out it was done. And then this other one... I don't know. I guess they did learn, they're learning to use the stuff they learned before. To figure this one out. So that's kind of good...

R2: Yeah I think my students for the most part really enjoy this. I've had one student come to me saying "This is my favorite lab of the whole semester because I have to figure everything out for myself."

R: Really?

R2: And umm..for some I think it may be frustrating. I have one student who comes to me almost every ten minutes saying "OK. What do I need to do next?" or "I want to do this. Is that OK?" And then I tell him "Well, go try it. Go do it yourself." So there's some that need step by step--"Do this. Do this. Do this." And with these unknown labs they don't have that. So some are not quite sure, but for the most part I think the students are challenged by it, and they enjoy it.

6.4 Character of Student-student interaction

6.4.1 Informal interactions: cliques

Although the TA quoted below does not usually have students work in groups, s/he perceives benefits in students working in groups.

R: Generally not group work, except for the one quiz...that I gave on the lecture material. I let them work together on that because I thought that they could benefit from each other showing them how to do stuff. But for the most part it's me standing up in the front of the room and fielding questions from them, for the most part. Or, if I've prepared something, just lecturing about the topic...

Most TAs had noticed informal development of groups or cliques.

R: ...They've pretty much found their own network of study buddies, or whatever, and they know who knows what and kind of go about it .

I: *...If you could describe the student to student relationship in the labs and in the -*

R: I think they like each other, but it seems to be the same people grouping up with the same people.

I: *How do they do it? Do they have to do it all together, or they just do it on their own?*

R: I think we've only had one or two labs this semester where they had to group up, but they seem to collaborate, I guess. I had students named [student name] and [student name]. They're always together. I'd call them [made up name]. And [student name] and one of these guys, they're always together. You usually see them just sitting like that...

I: So what about relationships between the little groups.

R: Oh, they get along fine. Yeah, they move around. Everyone knows each other and everyone has their own personality. They all joke around. I foster that relationship I think.

One TA related that the groups tended to be homogeneous in terms of abilities, personalities, and thought processes, and the similarity sometimes caused problems with respect to the demands on the TA and caused disruptiveness in the discussion setting.

> R: ...for the most part there's little groups that have formed.
>
> *I: Oh really? That have formed on their own?*
>
> R: Yeah, definitely formed on their own...I think they probably work on homework together somewhat. Sometimes I know that they've been discussing things. I know that they don't work on the homework entirely together. I know that, these two people are discussing the homework, but this one's ahead of this person, so I know that they're not doing it entirely together, but I think they speak to one another about it,... like the girl on this side of the room always talks to this other guy or they have specific people that they go to when they have questions about the lab. Sometimes because of instrumentation we have to work in groups. When that happens, they form their own groups, and it's usually the same ones, the same people work together.
>
> *I: That's interesting. What about the groups? Describe them to me, some of them.*
>
> R: I think in general the groups form as far as ability goes. Ability to do work and their thought process are very similar, the people that have hooked up together for the most part. So what I'm saying is they're isn't someone that gets it real quick with someone who's a little bit slower... These groups also, their personalities are a lot the same. Like, I haven't noticed that there's a really shy person and a very outgoing person. Usually the really quiet students are together, and the more outgoing students are together too. I think that that's what I observe the most.
>
> *I: How does that affect how you are to conduct lab or discussion, if it affects discussion?*
>
> R: It does affect discussion a little bit actually...because those groups sort of sit together, and sometimes they'll talk to each other, and that's a little bit difficult to handle. But in lab, like I said, three shy groups are together, the students that don't demand your attention as much. They tend to be more quiet and work more independently, and then there are students that are a lot more outgoing and are much more demanding of your attention, and it's really hard because sometimes you just have to say, "I'm gonna go."

One TA observed that groups have formed mainly along gender lines. (This was corroborated by LEAD observations.) This point relates to the matter of homogeneity of group composition noted by TAs above.

R: It's mainly by gender, for the most part. I can think of two groups, of the eight or nine groups that I have, two groups that are crossed, that have a male and a female. So there's just two that I can think of. And the rest are by gender for the most part... I don't know what that has to do with. I don't know if, you know, they live with each other on the same floor in the dorms so they know each other.

6.4.2 Lab groups encouraged by TAs, especially when equipment is limited

Most TAs indicated that due to lack of equipment students were asked to work in groups. However, most TAs noted that at other times the formation of the groups was voluntary. One TA speculated that these informal groups may have emerged from a context in which there was only one instructor but multiple peers to turn to for assistance.

R: We do kind of force the formation of certain groups for the limited equipment stuff. They also, in order to do their assignments, they work in groups... Some of them work by themselves, but they find--and we encourage this pretty much --that they do better work when they find somebody else and bounce things off of other people. So they get together and work on things by themselves on their [own] volition, that we never asked them to. Although occasionally, when a person's having trouble, we ask if they've worked with somebody else on this because sometimes it helps them to not go down all the blind alleys...We find that it helps for the students to work in groups sometimes on the homework problems and stuff like that. They spend so much time together that it just seems kind of natural that you would form groups together and ask advice because they can't all be talking to me at once. They can't all ask me. There are many times when I'm answering somebody else's question, and it's either, "Stand in line and wait for me," or, "Ask somebody else," so I think they naturally form groups together like that too.

6.4.3 Level of Competition varies by section

As the following excerpt illustrates, TAs' perspective varied with regard to the level of student competition in their sections.

R2: I had a kid who was an "A" student. He got "A"s on the tests, "A"s on his labs. He's just the number one student. And he didn't want to miss the lecture, because he was afraid I was going to say something that other people would then know and he wouldn't about a lab, or he was always wanting more information. He might show up and it wouldn't give him anything he didn't know. But at least he was there. And no one else got ahead of him or anything.

I: So it was really competitive.

R2: Competitive.

I: *Where do you think that competition came from?*

R2: He's got friends in the lab that he's had from the last semester. There's like a group of five of them who had the same TA last semester and so there always competing for scores.

I: Is it friendly or how...

R2: Oh yeah.

I: *What about the level of competition that you noticed?*

R: My class, I guess mine's a little different than, maybe some other ones but, I didn't notice, there's not really a competition between the students. I didn't notice.

I: *Yeah that's really interesting to me. Is there anything about the class that you, that fosters a lack of competition do you think? About the structure or..even the students.*

R: Well [the other TA] says that his/her students were always competing against each other. I didn't notice that mine were

R2: Because all yours get all As. There is no competition when you get all As. (all laugh)

I: *Is that true?*

R: My section is a good section, but, they don't get all As.

R2: It's more of a friendly rivalry just between people who have known each other before more than people who maybe in the class now that they don't know from last semester.

7. Grading Issues

7.1 High level of concern about grades noted

Many TAs noted that students were very concerned about grades. For example, two TAs noted that first-year students differed from upper division students in this respect and that this affected their teaching experience.

I: *What are the differences in the way you have to approach it [Chem 110 with freshmen students]?*

R2: I don't know so much differences in the way you approach it. They just have a different way of looking at things than older students. They have to have As on everything!

(all laugh) If they don't they're really upset. Whereas last semester, its like "Oh, I got a C. Oh well! Fine. I don't need this class anyway."

I: Are there ways that you help them deal with that? How do handle that?

R: I try to joke around with them a little bit. Try and tell them not to worry about their grades so much. I don't know if it helps or not but...

R2: I try to tell them that it's not that important, but they seem to think [that it is].

R: Well I suppose for some of them it is, kind of important but...

I: *Has that changed over the course of the semester or is that pretty constant?*

R2: No. They've really started worrying lately!

I: Even more.

R2: [They say] "How does the lab figure? How does this figure into our grades? How does this figure in...

7.2 Grading on the Curve Creates Anxiety

Two TAs discussed that although from their perspective students had been made very much aware of the grading system, some students still expressed concern and uncertainty because the lab grade curve had not been established.

I: At the beginning of the class some of them [students] talked about adjusting to the class: there was no syllabus, they weren't quite sure how they were being graded and those sorts of things. How well do you think they've adjusted?

R: They were told at the beginning of the year how they were graded.

I: *[Based on interviews] a lot of them didn't seem to get it then.*

R: Well, there's a couple different ways of looking at it. They were told what each part of the course is counted as the percentage of the whole, but they weren't told what the curve was. Well, you don't know until the end of the semester. They've got a pretty good idea now, but, I suppose being freshmen and being top students, they all want As, so it's just hard....

I: *[Is there an] effect... that these students aren't quite sure how they're graded?*

R: Well, from my standpoint, I don't think there is an uncertainty. We've told them from the beginning of the semester, lab is going to count x percentage of your total grade. And for some reason that doesn't sink in. I don't know how else to tell them that its 40% of your total grade. That's what it is! So, for me there's no uncertainty.

R2: Right. Same here.

I: *Well students do seem somewhat uncertain, and it sounds like your hearing it too. They're still asking you. They still don't seem to get it.*

R2: I think the curve maybe, what the curve is going to be. They know that its 40% of their grade. They know the breakdown, what everything is worth. So, 100% they know where all the percentages come from. They don't know what the curve is for each thing because for tests, "A"s went down to 80. On labs, we don't know what its going to go down to. We don't know until the end of the year. There's no way to tell.

I: *What do you think the effect of that is on the students?*

R2: Mine don't seem to mind. I told them that just yesterday.

R: I've got a couple that worry. I just tell them "90% or better you'll be guaranteed to get an A so."

Wright's Goals for Chem 110

Professor John Wright, along with his colleague Professor Claude Woods, believes that Chemistry Department goals for students in Chem 110 are understood in terms of a contrast with other first-year chemistry courses. In particular, Woods and Wright share the goal of ensuring that Chem 110 functions *not* as a survey course, but as a course that offers a challenging and stimulating experience for students who are serious about science and scientific thinking. In Wright's terms, he wants to "take advantage" of the unique nature of analytical chemistry to "train students about how to do science and how scientists think."

Without changing this basic goal that he continues to share with Claude Woods, Wright changed his goals for the *way* he wants students to learn as of the spring of 1992 (see Executive Summary, pp. 2-3). At that time, he decided the course should foster the problem-solving skills and creativity needed to solve difficult and realistic problems. While the content of analytical chemistry remains as important as ever, new and more general goals pertaining to the learning process emerged as critical. Wright elaborated in his first interview with the LEAD Center as follows:

> ...I want to get students in my course to be thinking. That's my real goal. ...if a student experiences the joys of just pure thinking and they do it again and again and again throughout their college career here, that they will start getting confidence in their own abilities... A lot of times students come through science courses now and feel like it's a big memorization exercise and that they don't really have the ability to understand these things in the way that a scientist would. That they're afraid that if they rely upon logic and thinking that they won't be able to do the problems, so they feel much more comfortable saying, just tell me what I need to know and I'll memorize it and spit it back on the examinations. And that's not what I'm after and I try to structure the course in a way that that kind of approach will fail for them. There's no way they can do anything in the course if they're going to rely upon memory.

In his second interview, he articulated yet other aspects of his goals for the course, as follows:

> Assessment is not at the pinnacle of what I'm after in the course. The essential thing that I'm after is giving students opportunities to creatively explore projects that have defined goals and in the process they improve their skills. It's then really neat to talk to them, and if that's because of an [oral] assessment being done, that's a good opportunity to talk to them... If you give them something for a project that does not have an answer and does not have a right way to do something, and they're convinced that there isn't a right way, then there is opportunity for them to be creative. And if they can get into that project so that they enjoy what they're doing, they consider it significant and worth their time, and they get ownership of what's going on. Then the emphasis for them is not on the grade that they're going to get, but on the pride that they take in doing it, as well as the experience of working together.

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Wright Lecture: From the Students' Points of View

Overview: Character of learning is connected, used, and conceptual.

1. Content is interconnected and used from beginning to end.

During the interviews students often said that their learning was positively affected by the connections among material learned from the first to the last day of class. This created a sense of in-depth learning. A female student spoke about this:

> S: I mean we haven't done that many different concepts per se, but gone really deep into what we did, I mean, like, "our friends the alpha fractions" (both laugh). That we learned the first week like came up, I mean we still use them and them and that was really weird. That we kept using things for the whole semester, I thought that was really strange. (laugh)
>
> *I: How come?*
>
> S: I don't know. Just because we've never really done that before. You know what I mean, it's like, "Remember this." But it was never like, "Remember this, and use it." So now its like...we can remember. He'd even say this, "You remember your old friends.," and we'd be like, "Alpha fractions!" (both laugh). And the sheet would go up on the projector, and we'd be like, "OK." You know, I mean, it's totally cool how we relate everything. Like to everything else. So it's really, really nice. I really like it.

The above student went on to say that because everything throughout the semester was related, she really learned to use alpha fractions:

> *I: How does that affect your learning, that things keep coming back and you have to use them?*
>
> S: Well, (laugh) it made me realize that I probably should have paid really close attention the first week! (both laugh) ...but I was thinking, "Oh, we'll do these for two weeks and then we'll move on." ...I wish I would have paid more attention, because I wish I would have realized that it was going to come back again, but, I totally learned them. Well obviously I don't know everything, but I learned a lot more than if I would have done the two-week thing. Because we know how to, like manipulate them now and (pause) everything we did, we learned how to use it.

In a focus group interview with three male students from Wright's class, all three discussed that everything in the course was "essentially all inter-related" and that this enabled them to understand the material better:

S1: ...it's been learning all throughout the year and not just learn something for the test and forget about it. Just everything keeps coming back. Like, alpha fractions we learned on the first day.

I: And you constantly have to apply it all throughout the semester?

S3: Yes, we just keep re-learning things. I like it a lot.

I: Okay.

S1: I've found that what I really liked about this was just the approach in terms of keeping it steady and consistent, you know...I think I liked when Professor Wright would talk about something, bring it back to what we'd done, and then move on again after we understand it, because that way we were learning more the, almost the approach, rather than the example. I think examples were something that I think he could have done more of, but I liked how he taught the approach methods, ...in lecture he'd say, he'd quote things like, "Well, we already know how to do this. It's back here. We did this already." So he'd work it through and he'd say, "Now, how do we do this? Well, we know how to do that too. That's back here." So he really tied it all up and gave it to us in a way that we could almost just do it ourselves now when it came down to it rather than, you know, trying to find an example like it in the book. It really generalized for me...

S2: I think I'm learning quite a bit, just because the way that - it's a little bit more of a narrow amount of material, and it's essentially all inter-related, somehow. It can all be used together, whereas in other courses it's, "Learn one thing. Cram for a midterm. Okay, go on to ideal gases, or something, and learn that. Cram for that midterm. Then it kind of all comes back together at the final." Whereas this is, "Since it's all related in some way, it keeps coming back." That way you're not forgetting the old stuff and not just concentrating on the new stuff that you're learning right now, so I think that's been really helpful to me in learning...

One of students went on to say that when "things kept coming back" in this course, he "realized that he was learning." Another student from above emphasized that it would be "tough for him to forget what he saw here."

S1: I like it almost where we're at right now, because we're basically done with the semester at this point. There's like one more unit on chromatography and we're done, but everything is really in a coherent little ball really. I mean, you can look at everything and see how they all relate back to stuff we saw in the very beginning, and in that way, I mean, it's the kind of material that it doesn't have anything to do with doing new topics or anything. Granted, he'd say, "Okay, we're starting something new now.," but every time, by 30 minutes into the lecture he's saying, "We're going to go back to here now and see how we figured this out." I think it's going to be really tough for me to forget what I saw here because there's so many inter-related things that it would be - I mean, to know one, you know other things from it.

This student went on to say that he had learned to problem solve in Chem 110.

S1: I think I learned - well, specifically in chemistry, I mean, I found basically what's almost one big procedure for solving all the problems we've seen this semester. I mean, there's little subsets, like some of them had to deal with batteries and some dealt with acid-base reactions and so on, but when it really came down to it, I'd say I learned a lot of problem solving. Just looking at the problem, seeing what I need to do, and starting to attack it piece by piece, and that was something really big that I think I learned this semester in chemistry.

Although most of the course was interrelated, a few students indicated that they would prefer to have more real-world context to give the material more meaning.

2. Lab and lecture are closely related.

Many students said that the lab and lecture were highly related and that this facilitated deep learning of the concepts:

I: Was there anything about the class, umm, besides the fact that it was just so in-depth that facilitated that kind of learning, that kind of in-depth [learning that you were speaking of]...

S: Well the labs, the fact that they (pause) run along. I mean, we'd do the labs and we're like, "Oh, look how this relates to lecture!" (laugh) I mean it was totally a unique thing really that lab and lecture went along so well. And it was, I don't know, so hard to describe because you'd think that that's the way class should go, kind of (laugh)

I: So has there been any chemistry that you've learned in the lab that would have been difficult to learn without the lab...?

S1: ...with our group projects, it really reinforced what we were learning in the lectures. It was more of tailored to the lecture and it just really helped suit your understanding of the information.

I: Are there particular concepts that you feel like, "Gosh, if I really hadn't done it hands on, and seen how these things react, I don't think I would have gotten this concept.?" Are there particular...

S1: It's just, I think that's the case for a lot of the things, that's the overall idea what you get from it. It helps a lot more to understand it.

Lab and lecture being related gave the students multiple opportunities to use concepts from lecture in an applied setting. The following student illuminated the difference between the activities in Wright's class and traditional problem solving:

S2: I think probably how I learn the most is through the group labs, because it seems as though - it's not like you're doing a problem or you're trying to solve something, but you're continuously thinking of new ways to do this, or going through the course material to figure out how you can solve a problem. It's almost like a continuous drilling, and I find that helps me the most.

I: That's interesting. How is it continuous drilling?

S2: Because you have this, kind of this broad problem that you have to solve, and you know it's going to kind of cover what you're doing in lecture right now, but it's really broad so you can't - you know, you have to kind of go through the whole material over and over again just to try and, you know, "Maybe we can use this. Maybe we can use another thing to figure out how to solve the problem or to do the lab."

A student who at first thought that the lab and lecture were not well related, felt that at the end of the semester they were much more related. She explained that this allowed her to concentrate on one subject:

S: Right now, umm, they've kind of come together a little bit more, because the lab we've been doing for the last month, umm, is a lot of the electrochemistry and we've been working on electrochemistry also in lecture. Which is really nice that they're actually a little more together now because we don't really have that much time to be doing two separate things, so it's nice.

I: Yeah. What affect does it have on your learning?

S: Umm, I think it just, I think it really helps it a lot because we're not trying to divide our time between three or four different things, we're just concentrating on, like, one subject. And it helps a lot if you just have one thing to think about at a time.

Two students expressed that it was essential to begin the group lab projects by grappling with the concepts from lecture:

S: You sit in lecture and you take notes and it makes sense, but in a very mathematical sense. You've got these equations and you're told that they work and you go through a proof and supposedly they work. But then, you go to lab and you see that they work and plus things...like in lecture we got lecture notes on electricity or whatever but it didn't really make sense. And then once we got to lab it had to make sense, otherwise we couldn't do the lab.

S: ...we just started a new group project a couple weeks ago which is to make a system that will give good data, that you can predict the data reasonably with the experimental data versus the calculated data and stuff...and using all the things that we learned already. Ever since the beginning all the same concepts are following through and it was hard--well like it was really a lot harder for us to actually get started on this one than the other one. Like to actually like come up with a plan. Like on the last group project we did we came up with a plan right away and started rolling, but this one we stumbled through it a lot in the beginning.

I: Why do you think that is?

S: I'm not sure exactly. Well I think part of it was that, like my group in particular really understood the stuff that we were doing last time, like we understood [the concepts]... and those concepts were really clear to us. But with this electricity thing we didn't really understand like what is was, you know to begin with. We understood what we were doing and that we, you like stick the little thing in and take little volt meters and write 'em down. But we didn't really understand electricity and so it was hard to come up with a plan--you know to do something when you don't fully understand it... And I mean especially when you're basically working from scratch. You know, you've got to come up with this plan all, you know like you know my group has three people and you know, three people together coming up with something that no one really understands, it was kind of hard.

Characteristics of Learning

This section details how the character of learning is a function of the level of students' participation, the type of class activity, and group dynamics.

1. Group/individual effects as experienced in different course activities.

1.1 Open-ended lab projects.

The students were required to work on research-oriented group projects. They were given specific goals, but very little in the way of instructions for how to achieve the goals. The students worked in their assigned groups on the projects and were graded in two ways. The group received an overall grade that was the same for each member and was based on a writeup of the project and an oral interview with Wright about the process and the outcomes. The group grade counted for eighty percent of the final individual grade. Each students then graded the other members of their group based on level of participation. Participation grades were determined by the average of each member's grade for an individual student. This portion of the grade counted for twenty percent of the total.

Students said that they focused on the process more than "getting it right the first time." Often students learned from knowing why their approach was wrong.

S: We had the two group projects. The first one. You do it, and, the main objective is, not that you are able to do it completely right and get everything to work out perfectly. But, and especially for this last project we did, we had to construct a theory for determining the potential we'd get-a certain PH-for a solution. We had to construct a theory and make a model using different agents. That was the first stage. And the second stage was testing if there were problems, and eliminate the problems by fixing things. And, I think that helps a lot to understanding it when you can correct your own errors and you can go back and find what is wrong, and it sticks in your mind, that much more of it. You know...why it was wrong.

Overall, participation grades did not seem to function as they were intended. In the groups where students reported that they worked equally well, many reported that they all gave each other 100% for participation grades. They did not, however, express that this grade was an incentive for the group members to work equally hard. A female student:

I: OK. Yeah I'm wondering, how did the participation grades go in your group?

S: I think we all gave each other 100s...I think we all deserved about the same, and so..I don't know [participation grades are]...kind of a useless endeavor, if the group is working well together, but if they're not then I guess it's a way to show [that].

In some groups where students reported an inequality in the contributions of group members, students gave each other full credit:

S: We like do grade ourselves also on that [on participation], like we just hand in a sheet but, I think like every single group gives full points to everybody,...pretty much. Yeah, so that's kind of,..I mean, it's a good idea but nobody wants to, like, detract points from anybody else and, so it really doesn't work out that well.

One student, however, did report that in his group there were two members who participated very little and he gave them below passing participation grades:

S: Well, two out of, for the second group project, essentially, it was, we have four people in it and, two people did the work. I did the experimental part, and then we had to write it up. And to make a long story short, I didn't have enough time to do it. So the other person who had an idea of what was going on, s/he typed it up. But for the other two people, when they did show up, one set up the pH meter, and the other person just [did] dishes on the short time that s/he was there. So. (laugh)

I: So how did that leave you feeling?

S: Well I was a little upset but you can grade the people. You... grade how the person did and obviously when the person doesn't show up you're not going to give her/him high marks...like our group, I think out a 100 I gave one [student] like 5 points, because s/he was never there. And then the other [person] I think I gave maybe a 50 or something, because s/he was there every time but, it's just that s/he set up the pH meter.

One student said that the most important part of the participation grades for him were the comments. He changed his behavior in the group because of his members' negative comments.

S1: I know at least the thing I think was more important in that group grading than the grades themselves were the comments people were writing, cause the grades themselves were just, you know, they were points. It was like, "You scored this." "Well, whatever." But like on that first one, I mean, people [were] writing comments like, "You're being way too domineering. Calm down. Let people finish," you know, "Do this." That was the real constructive thing that I think was a benefit to me from the group grading.

He went on to explain how he changed:

S1: I can say overall, like by the second group lab, we pretty much, we gave each other 100's, cause we were very impressed with the results...The first group lab I got a lot lower score than the other two people gave each other, and whatever, but that had - no, that was an honest thing because I admit that in that first group I was trying to be really domineering, I was trying to be kind of, well, "Let's get organized," when, you know, we already are. Yeah, it was the kind of thing where I just sort of mellowed out in the second one, and it worked out better.

Several students said that even if they gave the whole group nearly full credit, they would give themself a lower grade.

S: ...I mean, I was giving them 98, 99, like on the first - I gave myself pretty much just a little less because - I think anybody, I don't know, you tend to feel that you're doing a little bit less than the other people are or something. It's just something I kind of felt was generally the case, but it was more...a guilt factor, than what it really maybe represented.

A student who was having great difficulty with other group members said:

S: ...I don't grade low for anything, generally. I just, it's like around the same score that we get on the project overall. So like on the last one we got like a 90 on the project. So I [gave participation] scores around 92 and 93. It's not like a huge deduction, but it's something that Professor Wright might see and..realize.

I: Yeah, that's interesting because its sounds like your opinion is much lower than that. Why do you choose to?

S: I don't know. Because when I actually look at the, the things that we're grading on. Like group skills. I mean they do bring a lot to the group. And they do add a lot to the group. They treat me like crap, but that's not actually one of the categories. (laugh)

I: Oh, really? What are the categories?

S: I think it's like, group skills, contributions, umm, overall opinion, or overall. I guess it could come in there. But it's mostly just your working environment, it's not your relationship as a group.

This student went on to relate that the participation grade categories reflected the values in the scientific world where "niceness doesn't really count."

S: I mean, if we want to be as fair as we can, they bring a lot to the group, and they add to the understanding overall as the group. Umm, they're incredibly intelligent. Umm..but, they're not very nice people. So, umm, but niceness doesn't really come in science. I mean, either you discover the cure for cancer or you don't. But if you're nice, I guess people don't care... I guess it doesn't really matter in a lot of jobs.

I: Hm. Does that concern you at all or what?

S: Yeah! A lot! Because I think our society as a whole is, really going downhill I think. Because people don't care, I don't think, a lot about other people. But...

I: Does that have any impact on what, on [your career plans]?...You're going into medicine?

S: Mmhm.

I: Does that have any impact on, what you plan to do in the future or...

S: Umm, well..actually (both laugh). Me and one of my friends want to open a low income clinic. In like an urban idea. So it kind of impacts us just because, we really want to make a difference, and we want to be the good guys. And I guess our experience with bad people just, shows us what we don't want to be. (both laugh)

1.2 Problems Sets

Many students related that it was while doing the problem sets that they really learned the lecture material.

S: ...the assignments and the take home tests especially are a huge learning tool. Because, I mean, you can listen all you want in lecture and in discussion, but until you actually sit down to try to do it, you don't know if you can. And then you find out 'Wow! This is really hard!' (laugh)

S: I go to lecture and I listen but when I go home and do the problems I'm learning it, I mean for real. I'm learning how to apply it...by doing it. I'm, like, learning how to use all the equations the right way, and what they mean and...actually...understanding the equations more when I'm at home working on them. You know something will occur to me when I'm at home and I'll go, "Oh! that's how that works!" And then usually, the [during] lecture sometimes I'll..see things, but...it's just kind of on the surface when I'm in lecture. I'm...soaking it in and later on [while doing homework] I'll digest all of it.

Most felt that the homework helped them prepare for the tests:

I: ...What about the problem sets - what role do they play for you?

S: I think that they're very good preparation for the test. (laugh) And I'm glad that they make us do them. (both laugh). But they're graded. Because a lot of times, you know when they're not graded you just kind of [think], "I'll try it, [but] if I don't get it." (both laugh) But when they're graded you have to do them, and because the tests are very similar to the problem sets, I think that that's really (laugh) a good idea to make us do them so..

Some students have difficulty with the homework in making the necessary conceptual leaps.

S: ...I understand the questions, and I understand when he explains it, but I couldn't have gone from point A to point B on my own. Which I think is a limitation. Because I obviously needed someone to hold me by the hand and take me from point A to point B. Umm, and I could go from point A to point B on my own now, but I can't do it on my own to begin with, which I think is a limitation.

1.3 Discussion sections.

1.3.1 Time slots.

A problem that students (in both Chem 110 sections) frequently mentioned was the 7:45am time slot for discussion. Many students felt that they and the TAs were not at their best at this time and that this diminished their productivity in discussion.

1.3.2 Discussions with the Teaching Assistant.

TAs were free to organize discussion according to their own beliefs regarding the students' needs. Students expressed that discussion time spent talking with the TA and the other students helped, but was not essential. This was largely due to the high level of interaction among the TAs and the students in the lab. The following quote is more positive than others:

S: I thought the discussion was useful. I mean I have, I never missed any of them. No, even though it was at 7:45!...I think it was a good place to get questions worked out. I mean, I'd hear other people's...questions, and, you know, I'd think about it and I'd ask my own and you know you think about it. Umm..you can get more into detail with your questions than you can in lecture...And because we see [out TA] eight hours during the rest of the week too, you know, we ask him questions then about problem sets or whatever, but..So, I don't know, [discussion] was..it was useful..[but] I mean if it hadn't been there, I don't think it would have been any big deal.

1.3.3 Quizzes.

Some TAs emphasized quizzes, spending the bulk of the discussion sessions on hour-long quizzes, while other TAs gave only a few short quizzes. Thus, learning from quizzes varied. However, for the most part students did not report that quizzes played a significant role in their learning process. In some cases the effect was minimally positive, but in other cases, students felt that the quizzes were ineffective and detracted from needed discussion time.

Most students who had hour-long group quizzes in their discussion sections, indicated that they did not value these quizzes as they were too difficult for the time allotted and took away time from needed discussion time.

Several students related that quizzes were ineffective because there was not enough time to really learn anything. This contrasts with the take home exams, which they also work on in groups, but with ample time. The two students quoted below both said that with the quizzes, there were only two options: either you understood it or you didn't:

S: Umm..I think I would say discussion [was the least valuable component of this class], only, just because it meets only one hour a week. And usually what we end up doing is taking a quiz, which isn't much of a learning tool because either you know it by the quiz time or you don't. You're not really learning anything new...

I: ...How is that different from the take home stuff?

S: Umm, the take home stuff you have time. You have lots and lots and lots of time to work on it. (laugh) And umm, usually at least in my group, we try to work on it quite a bit on our own before we work on it together. So that we're not just, you know..coming up with our ideas together.

S2: It depends on the material. If I happen to like, or understand better, I can do the quiz and then I know how to do this problem. But when I am totally lost I just copy from others.

I: You just learn from others, you said, or just go with the others.

S2: Yeah, we work in groups so, yeah, if someone from the group knows how to do it we just copy it, see.

I: I see. And so, when you just copy it from someone, do you feel like you are learning it, or does that help or

S2: When I don't really understand it, I don't feel like I am learning it.

The student quoted below said that after his discussion section complained about the difficulty of the quizzes and expressed to their TA that they felt they were a "waste of time," the TA began to use to discussion sections to address the problem sets. This student valued this use of the hour much more than the quizzes:

S1: ...the first time a lot of people in the group finally voiced and said, "Look, this is really tough. We don't want to waste our time on a quiz. Would you mind doing a discussion on this?" And he was real open to the idea and everything. Since attendance was required, that wasn't really the thing, so he just said, "Okay, great. Everybody bring their problems, and we'll do those." So I think toward the end of the year the discussion got a lot more useful that way, since the problem sets became so much a part of midterms and then understanding lectures...Like I said, at the beginning of the year they [the quizzes] really weren't [valuable] because they were just, you know, such a high level that it basically took the group to understand what was going on...

One student indicated that the hour-long quizzes provided a challenge and were valuable because of the group work:

S: ...quizzes, they were good, I mean they were good, because they were real problems, and we had to think about them. And I guess I like that better than having stupid, dumb, retarded quizzes that, you know you're just like, "Oh, OK. I know this formula"...and then you're done...I'd rather do those [good quizzes] because we were working in groups and they were really representative of, like, what we were actually working on. So..for me that was good because it would be like, "Oh, you know. Now I see how some of the things..," like if he had just been doing theory in lecture, and hadn't got to any problems yet I can say, "OK. Now here's how a problem works." And I get that. I mean, usually he did problems in class too, but if he hadn't gotten to them, because my discussion is on Friday, before the Friday lecture, so a lot of times during the Friday lecture he'd be doing problems and I'd be like, "Oh! This is the stuff we did in discussion."

At least one TA abandoned the difficult group-work quizzes and returned to problem-set oriented individual-work quizzes. The following student reported that this was helpful.

S3: ...the last couple weeks, I don't know if it was the TA's decision or if it just happened, but our quizzes have gotten more like problems we'd see, but quite a bit easier, and problems we might actually have to do on a problem set. So, they've really become kind of helpful.

I: And it's the group quizzes again?

S3: No, cause we did kind of cruddy on our first test as a group, so he decided we needed more practice doing things on our own.

1.4 Take-home (group) exams.

Some students reported that they first began working together on the group exams.

S: ...at the beginning...lab wasn't as much in groups. We didn't do as many group projects. It was clear from the beginning that it was encouraged that you do your homework and stuff in groups. But...there wasn't that big group feeling until you know probably like probably the first cooperative exam...But by the time the first cooperative exam came, everyone started working together, and then we started doing these group labs and group projects and that brought us all more together.

The only students who reported attempting to do these exams by themselves found them extremely challenging. (See 3.1.3.2: Take home exams.)

1.5 In-class individual exams.

Students' expressed varying perceptions of the level of difficulty of the exams. Some students felt that the exams were a challenging test of their understanding.

S: ...they're hard, but they're definitely like workable. I mean, somebody got a 100 on the test. So they're definitely workable and, I mean, but then again somebody else got a 19, so it went, the range is just incredible but, I think it has to do with the fact that some people do the work and some people don't. (laugh). And the person who got the 19 I don't think did very much of the homework on his own or her own or whatever...I mean I got an 88 on the test. And I've done the homework and so I feel like I actually understood it...A lot of times on tests you know you come out you're like, "Wow! I pulled that out of nowhere!" you know, "That grade doesn't ...I was just lucky!" But I don't think that I'm lucky on Chem tests because I think that we really learn the stuff.

Several students had trouble with the tests and the difficulty of the problems. The following student states that he feels that the tests are not a measure of understanding, because they are too difficult:

S3: I think I understand stuff really well, but I guess I'm not really a good test taker. I don't think the tests are really geared for how well we understand the general knowledge of the -

I: What do you mean?

S3: I think the tests tend to be a lot tougher than anything we've ever done up to that point.

He and another male student went on to question the basis of the tests.

S3: Another thing I was wondering about was, I mean, if you have a test and the average score is a 60, how well are you testing how well they know the material? That's the only thing I'm wondering. I mean, if the majority of the class only does a little more than half the problems right, is that really testing how well they know the general material?...

S1: I guess I kind of wonder about that, then, though, too. If that's true, then how well are the people working in a solo situation, if that's what they have to do? I don't know. I guess it's kind of a - it's actually both of them. You know, one is to say, "What is the test measuring?" and two, "If it is in fact measuring individual performance, how important is that?"

I: Given that the class focuses so much on group work?

S1: Right.

S3: And in life, are things really -

S1: Exactly.

S3: You don't have to work by yourself, you don't have to have a time constraint. Well, you do have a time constraint, but not of that proportion. I don't know. I personally don't think tests are tests of anybody's knowledge. Some people are good test takers, some aren't.

Several students said that they were adjusting to the use of the full scale, from 0 -100, for grading.

S: ...Like in high school it was 94 and above was an A. It was, and 94 and above was easy. It was so easy! And now its like 'Ooh! 62!' Let's not translate that into any past experiences or we might be depressed! (both laugh)

I: How did you make that adjustment?

S: Umm. It was actually a pretty tough adjustment to begin with. But, I deserved the adjustment at the beginning, because I wasn't working in Chem 109. I didn't deserve any higher than the grade I got. Umm, but it was still a really tough adjustment, because I had worked as hard as I had in high school. But..(laugh)

Some students were demoralization by taking the tests, but more students were positive about the second exam than the first.

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The following quotes illustrate that a few students who had felt upset about their performance on the first test, largely because they felt it was too difficult, had more confidence and performed better on the second exam:

> *I:...so how did you feel after you left the class, after you left the exam, before you got a grade?*
>
> S: Umm, I felt pretty confident. Umm, I felt more confident than 62% [which is what I received] But that's happened on every single test I've taken since I got to college. I think I know what I did but then I get it back and I'm like 'Huh?' Umm, but , umm, even last semester I would take a test and I'd be like, "Oooh! Nice question. Next one!" (both laugh) But umm, I actually, I worked out, I worked on all the problems then I, you know, had a good line of reasoning...

> *I: How is Chem 110 going?*
>
> S1: Better...Better that it was last time.
>
> *I: Do you have any idea why?*
>
> S1: ...on the first exam I didn't have any idea, but on this exam I, we just had one a week ago and I was able to do all the questions.
>
> *I: So you don't have any idea whether you put in more effort or whether the material got easier?*
>
> S1: I think I just, I am not sure why, I just understood it better.
>
> *I: Just sort of came to you.*
>
> S1: I think the lecturers were clearer, so, I was happy after and when I got it back.

The students' feelings about the exams may be related to the perception that Wright more closely tailored his lectures toward the problem sets during the later part of the semester.

> S: ...So I think toward the end of the year the discussion got a lot more useful that way, since the problem sets became so much a part of midterms and then understanding lectures.

> S2: Yeah, it seems that he is doing more examples. I don't know if it's because of the - it might be just because of the new stuff we're doing, but it seems that it's not as much theory...he'll spend some time going through examples.
>
> *I: [He'll] actually go from start to finish on a problem, taking you through step-by-step?*

> S2: Yeah, whereas I don't really remember that being done as often before.
>
> S1: I have seen him do more lately now where he'll say, "Does everybody understand this?" and if he gets a murmur from the class, he'll start over from scratch to make sure that people are getting it step by step...I like it better now than I did before [when he didn't do that as much].

1.6 First Class Client.

During the first set of interviews, students tended to say that they had not used First-Class Client (the computer networking bulletin board available to Wright's students). Many students, however, related that during the last group project, Wright required them to post insights on First-Class Client. They were also required to cite findings from other groups' reports. Students were then able to piggy back off each other's ideas.

Many students reported that this networking increased the feeling of the whole class working together and enhanced the benefits of group work by enlarging their circle of students:

> S: So then we started reading what other people were doing and um, what went wrong with other people's groups and what went right with other people's groups, and then we started (pause) understanding what was going on...Like if you take someone else's idea that they did for theirs, you have to acknowledge that you did... And also you can't totally trust every, you know what other people are doing either so once you get an idea from another group, you have to go and experiment it yourself to make sure it works.

> S: You have a basic idea, and you do titrations and stuff to get different information that you know you need to do it. As you're doing it, you figure out more things that you need to do. And just talking back and fourth with other groups with what they're doing. It just helps, it helps a lot. With this last project that we just got done with. When we'd finished with the first stage of it, he required us to post our experimental data, on first class client...So that you could at what other students were doing and, if you're experiencing problems, maybe find out what, if another group's information can help you...it helped to help figure out what was wrong in some cases, to see, if your's wasn't working right, if another group's was, kind of what the reason was.

The student quoted above had said in his first interview that he felt there was a fairly high degree of competition among students in Chem 110. He explained that he no longer felt this way, and that the exchange of information and adjusting to the structure of the class were the factors that created this change:

I: So have you noticed any changes, or any thoughts about the students interactions?

S1: I think the more we've been working together, and it's pretty much the lab setting where everybody is together. It think it has become a little bit more relaxed and stuff. Your lab group is like your family. (laughing) We've done quite a bit together. I think it's gotten better.

I: It seems like you felt like it was a little bit fractured before. How did that change come about?

S1: I don't know. I just, it was almost like, just, middle of the semester, kind of change. With this, kind of like in between group projects...You had to post your information on First Class Client, and it was almost like the entire lecture was working together. Everybody was working towards the same thing. You'd talk to anybody and everybody to get ideas...It just seems a little bit more relaxed atmosphere than it was. I think starting out the semester, everybody was really worried about doing well. Just as it progressed, it kind of settled into the framework of the class.

1.7 Student Board of Directors.

As another component to this class, Wright has established a student Board of Directors, a group of students that meets regularly with Wright to discuss any issues that arise throughout the semester. The overall perceptions of the board was that it had some influence, particularly in regulating the workload.

To varying degrees, the Board of Directors contributed to the students' sense of ownership in this course. Perhaps this is true more for the board members themselves than for the class as a whole, because non-board members rarely, mentioned the board of directors without prompting.

One board member commented that she felt that she had a voice:

S: I kinda like the board of directors. I mean, it's only eight people, and you sit there, and are talking to him, and it just seems...kind of close, you know. He asks, you know, "Ok, so what do you guys want to talk about today?" And we'll say, "Alright, well, we didn't like this, and we didn't like that. Oh, well, some of it was OK, and we really didn't like this." He sits there and takes notes on what we are saying. He actually listens and changes things because of what we are saying. And that is always a nice feeling, you know. Thinking he does actually care what his students think. And, you know, if we tell him there is too much work, he doesn't necessarily cut down on the work, but he will think about it more. He might assign different sorts of problems, or otherwise he was going to make six things due on one day, and he'll kind of spread things out a little bit, you know. It is nice to think that he's actually listening. Plus we have gotten to know him better, I think. The board members have.

The above student went on to talk about the personal effect of her experience on the board:

> S: It is nice because you know that he actually knows who you are, you know. And you think, "He knows me." It is almost like motivation, because, you think, "I have to do well on this test, or he's going to know." And it's not that he is going to say anything to you about how badly you did, "Oh, God. You must be dumb."... It's just that it gives you expectations of yourself that you might not have had before. Thinking that, "Oh, I have to do well on this test not only for me, but because I see him every day, really close up." (laughs)

Another board member related that she felt the power of the board to really make changes only existed during the early part of the semester:

> S: Umm, we haven't really made any decisions lately. We just kind of sit down and talk about the class and then we're done. We don't like really say, "Well this is a problem, let's change it." Because there's not really much to change anymore. Because the decisions we made at the beginning of the semester were to take place throughout the semester...

The following excerpt is from an interview with three male students. They indicate that although they had little connection with the Board they felt that, to some extent, the students' concerns had been heard and that some changes had resulted.

> S2: I haven't really taken advantage of the whole Board of Directors thing and speaking to them. I think that's just because I didn't really have any problems with the course, and a lot of the stuff that I would say ended up - I'm saying anyway.
>
> S1: I didn't really have any connections with them at all because our section didn't have a representative, so really it was out of our hands. We didn't - it was the sort of thing where we kind of hoped the Board of Directors would do what we wanted, and for the most part they did, but my section really didn't have any direct representation....
>
> S2: I think it worked out really well, and it seemed as though they had a lot of pull...It seemed like pretty much if they expressed a concern it would get done.
>
> *I: So you saw some things change through that?*
>
> S2: To a degree.
>
> S1: I saw that too. Even though I really didn't have the connections there, I could see, like when the entire class was behind on something, they were quick to say, "Let's move the date back a couple days, because no one is getting this done," and for the most part the professor would agree with that...Yeah, I think it was important because sometimes the board would bring up something that was obvious to all the students but that the professor kind of missed. So it was a good voice that way, I think.

2. Student-instructor interactions.

2.1 Professor encourages students to interact with him during and after lecture, which fosters thinking.

Many students commented that Wright wanted them to take an active part in the lectures:

S: Well he'd explain them [the mathematical model] and then he'd ask us questions on what we thought what would happen to try and figure out our ideas. And then he [would] comment on those [ideas] and try and have us build on those. And then when it--since most of [the] ideas presented by the students were correct then he [would] continue and show how that would apply.

I: What if they were not correct?

S: He, well usually I thought that he would ask why the person would think that or he'd explain why that wouldn't be the case. Or... he'd explain why that wouldn't be the case.

I: OK. So he'd actually go through and he ask for the students reasoning? And then if the student was correct he'd continue on?

S: Oh, yeah there were many ways that he could do it. He['d] just say "Does anyone have any more ideas?"

Some students acted on Wright's encouragement and others did not, but the general feeling was that students were more "on their toes" because they knew they might be called upon to take part in the class.

The following student related her surprise at Wright calling on her and the sense of permission to take an active part in the class that she felt:

S: ...the first day or the second day in class, he called on me [by name], like out of nowhere. Because he's like, "Well, you know, I think I'm going to ask somebody from the class." ...And I'm like, "Whoooah!" (both laugh) You know. "Help!" And he was like, "Well, what did you get for this?," and I'm like, "Umm..you know, OK. Being called on in lecture, this is weird." ...It was scary, but I mean I think that maybe that might have even helped, like, later on because then I was like, "Well, you know, I can talk!" (both laugh). "You started this! I can talk now!" So...that was nice...I mean I don't know for sure but I think it would have helped other people too. You know, to say, "Well you know, he obviously wants contributions from the class." If you know he's actually asking.

This student pointed out that the professor wanted to know how she worked out her answer:

S: ...So I mean, [when he called on me to give the solution] because that was like a problem he had done. And he wanted like what I had gotten for the answer and how I had gotten it, rather than him just standing up there and working it out.

One student said that Wright had called on her in class and her confusion about the material became clear, so he asked her if she would like to meet about the material. She met with him and he worked with her until her understanding was greater.

I: How did it come about that you ended up working for several hours with him?

S: In class he does the problems for the day. And I knew what he was talking about, and he called on me to answer the question. And...I knew how do to it, just like surface, you know, what equation to use, whatever. And so I told him the equation, and he said, "Oh. OK, so what you did is you took this equation, and you manipulated this, and you did that, and you got the answer, and you did this and that. " And I go, "Oh, yeah. Sure, that's what I did." I had no idea. He said, "What did you do next?" And I am like, "Ummmm." I told him what equation I used next, and how I would go about doing that. He said, "Oh, yeah. OK, that would work. So what you did here you got from the first equation. You did this and this and that." I went, "Sure." ...I had no idea.

I: So was he assuming you had a much deeper understanding?

S: I guess he probably figured I knew where I got these equations from. (Laughs) I got them from [a classmate]. "Ask her!" I would have gotten those particular equations, but I didn't know where they came from. And so after class, he said, "Um do you want meet to at all to talk about class at all?" I am like, "Oh, yeah, that would probably be good." (laughs.)

I: So what did you do when you met with each other? How did you approach...

S: We basically worked on one of the problem sets that he handed out in class, because there is like 50 problems in each problem set. We don't have to do all those. I just basically worked on problems with him. Just and. He wouldn't have me do the problem, he would say, "What's going on with the solution?" I am like, "I don't know they're molecules! You can't see them!" (Laughter!) He'd say, "OK, let's draw a picture of what's going on." And so generally, just you know, understanding what was going on, and then, say, "Here is the problem we are doing. Now figure it out, knowing what is going on." So we worked on lots of problems like that.

I: So what was the outcome for you?

S: I definitely understood it better than before I went into see him. I think people still understand it better than I do, but I was pretty happy with at least understanding what concepts I was supposed to be knowing and understanding actually what was happening . I think actually it was pretty helpful.

A student who frequently spoke in class said that she felt free to explore complex theoretical questions in lecture and that this contributed to a higher level of learning.

> S: ...a lot of times more I'm asking like theory things you know, like, "Well, what would happen [if]?" or, "Why aren't we accounting for this?" A lot of people ask questions like that.
>
> *I: Yeah, I noticed that. I noticed that there were some really high level questions...when I observed in the classes. So what does that do for you that you can do that? Is that unique for you?*
>
> S: Well, I think you actually think about it, rather than like if you know that you can't ask, and...if you know you can't ask you just kind of [sit and say to yourself], "Ohhhh. Who cares?" ...But if...you're thinking to yourself, "Well, what would happen if we do that?" And then you kind of look at it for a second, and you say, "Yeah, what would happen if we do that?" and then you raise your hand and you say to him, "What happens if we do this?" and he says, "Well (pause)," and he goes into it and tells you, and you're like, "Oh, cool. (laugh) Cool, now I know." But if it wasn't an option to ask questions like that I think that the thought process might just stop. Because I mean, I would probably never go into office hours to say, "What would happen if you do this?"....
>
> *I: What affect, if any, has the ability to ask those kind of questions in class had on your learning?*
>
> S: I think it's helped. Definitely. Because I do think more and further about things than I do a lot of other times...

2.2 Grading Issues.

2.2.1 Professor perceived as striving to grade for understanding.

Most students felt Wright strove to grade them on their understanding of the concepts, rather than simply on getting the correct answer. Students appreciated this and indicated that they felt less pressure to perform in the way that they were accustomed and to focus more on integral learning:

> S: [The way this course is graded] takes some of the pressure off. Where it's more working until you do understand...It kind of accomplishes one of his main goals, where he doesn't want the focus of the course to be memorization, at all. So then you don't have to worry about memorizing everything and knowing it the first time. You work at it, figure out things that are wrong with it, and it gives you a chance to correct for what you don't understand. You learn it better.

S: ...Well like with the laser attenuator we went in and we got graded, and we actually got an A on it. Umm, we almost all started crying we were so happy, because it turned out so bad! Like our results were kind of off, but he like grades your procedure and your ideas and, you can explain why you think it went wrong. And you know, that's also good to know what your problems were so. He grades on your knowledge that you brought into it and took away from it. Not necessarily what you actually accomplished. Which is really good.

2.2.2 Students' perceptions about match between their learning and the group grade on lab projects.

A student who explained that his group used a system of division of labor felt that there was a good match between their understanding (collectively and individually) and their grade:

S: At the very end I think the grade the entire group got did reflect what all the group members understood, because generally the day or two before we came to the final report written up, everybody would get together and we'd say, "Okay, do you see why this happened?" Granted, you didn't understand it then, but, "Let's take a look at it now and get it all worked out."

Some students felt that their grade was lower than their level of understanding and lower than they would expect given the amount of time and effort expended on the project. The following student indicated that she felt the grading criteria in this case was "getting the right answer."

S: But, the last one that we went in, well we didn't do bad on it, we got an 84. We spent like 25 or 30 hours on this project, I mean, it must have been that much...So we were like, he's like 'Well I'm going to give you an 84.' and we're like, we all just looked at him. (laughs) We were just waiting there, he goes 'You guys look kind of glum.' And we're like (facial expression) (both laugh). I think we made him feel bad. But we spent so much time on it, it was just like, I don't know, its just hard to comprehend that spending so much time can mean an 84 I guess. I mean, it was just like..I don't know. It was really frustrating, but , I mean I guess that was kind of real life. You know, you can spend a lot of time on something and still not do really well on it, so but we were just like 'Whooah!'...

I: Do you think that the grade reflected the group's level of understanding?

S: No. I don't at all. That's what, that's I think what disappointed me the most, is the experiment was to, we had to make a solution and then run a laser through it and predict..or by making a solution a certain way get a certain intensity of light out. Our's didn't work..but the reason why was because of something we had read in the book. And, well, we based an assumption on something in the book and it wasn't correct. And when we realized that we went back and we reworked all of our data so that, like, how we would have done it, had we not made that assumption and we had the correct, like solution and everything there..and so I

> really think that we understood it completely, like if we had done it with that solution. We asked our TA if we could redo and he said, "No." And so, well the reason being is because it was supposed to be a one shot deal and that I can understand, but...we gave my calculations and everything and I really think we understood it a lot better than an 84 so...
>
> *I: So where do you think the grade came from?*
>
> S: Umm..the fact that we did it wrong the first time. But I mean that's important too because, if you know, in the real world, if you screw up, you screw up!

Some students reported that they had a lower understanding than their group grade reflected, and that this was due in part to the fact that the oral assessment interview used for determining the grade was primarily a dialogue between Wright and the one or two people who did the conceptual work and understood it:

> S: [We] went through the interview, and we just kind of like explained everything in the paper that we wrote up. Like, he said our numbers came up pretty well, and he kind of liked what we did. Said we took a unique approach and stuff. He gave us a 95 out of a 100 on it.
>
> *I: Hm. Well that's kind of neat. Who did he direct the questions to, and how did that...*
>
> S: Well mainly, mainly the person who wrote up the paper talked, because she, like some of the stuff that she put in there we..didn't quite know...So, she pretty much tried explaining everything that she did in the paper because she's the one who typed it up and stuff so its easiest for her to explain it. And then my other lab partner who did quite a bit of the work, kind of told, basic all around what we did. And I just kind of sat in and listened.
>
> *I: Yeah. Did you feel like the grade reflected your level of understanding? Your own level of understanding?*
>
> S: Uh, not really. I kind of felt guilty about that, because at the beginning of the project I did do quite a bit of work, but then towards the end I just kind of like, started losing my interest in school and...started like, not doing as much work, which was like when it was most important when we were finally getting the basic, the results of it all. So..I had a little, I had an understanding of what was going on. But everything we did with like the spreadsheets and stuff I, didn't even look over or anything. That I really didn't understand that well.

2.2.3 Individual testing insures that group work fosters both independence and interdependence.

Students who reported that they had done well on the tests tended to report that they had made sure of their own understanding of all group work. Conversely, students who did poorly on tests indicated that their understanding of certain aspects of their group's work was *shaky. It is natural to conclude that the tests acted to insure that group work fostered not only interdependence but independence as well.*

In the following quote a student expressed that the students in her lab group were interested in learning from the group lab project because the projects were relevant to the lecture material and to the test.

> *I: Why do you think that happened [that all of the members of your group worked equally hard]?*
>
> S: ...Because everybody wants to learn it. Because what usually happens is the people who don't really, you know they're like, "Oh, as long as we get an A on the project, I don't care." But everybody in our group is like, "I don't care if I get an A, I need to know the stuff, because its going to be on the test," so...It was cool that way.

A student who worked in groups on occasion, but who only worked to get the right answers, indicated that he did not do well on the tests:

> S: Like, when, ...Dr. Wright, has us, like, work in groups or something in class or...for our quizzes it's actually kind of nice, though, since we get to work as a group. And I'm having a little bit of a trouble understanding. That kind of helps out, but it's really not helping [me] learn..like what I need to..like grasp the concepts of the class.
>
> *I: Yeah, and then when you go to take the exam?*
>
> S: Then when I take the exams I kind of bomb out. Or at least on the last one I did.

Similarly, students who worked primarily alone and did not benefit from an exchange of perspectives, ideas, and knowledge, tended to do poorly on the tests as well. (See section 3.1.4: Cramming for exams.)

2.3 Teaching Assistants perceived as helpful, but not essential.

Students perceived the TAs as important to their learning experience, but not central to it. The primary relationships were student-to-student. It may be that our interview protocol de-emphasized the role of the TA and had we devoted more attention to TA issues, a different picture might have emerged.

2.3.1 Teaching assistants vary as a source of support.

Students reported that some TAs were very supportive and others, were less able to offer support. The following two students spoke about the same TA.

S: It's fun. He's just really silly sometimes, and we need an attention breaker a lot. A lot, a lot, a lot of times. I think he understands the pressure that we're under. So he tries to make things, you know, as smooth and, I think, as doable as he can for us.

I: How does he do that?

S: Umm...He...doesn't get down on us about anything ever. You know, if we really just need help, you know he's there. ...He's just silly sometimes, like when we try to name twenty characters from the Brady Bunch. (both laugh) Umm...

I: Twenty? Were there twenty?

S: Well you know, like Sam the butcher, and the little kids friends and stuff. Umm, so we just do stupid things I guess that..kind of get us through.

I: What grade would you give the TA for their performance in the class?

S: My TA you mean? I think I would grade the TA highly. I think the TA is a very good TA, and the TA has the - I mean, the TA is very keen also on what people need. Like the TA is not going to tell you something s/he thinks you can figure our by yourself. If s/he thinks that you're capable of figuring out that, s/he won't--it's weird cause we've noticed that s/he helps different groups out differently. Like s/he might help one group a lot and help another groups a little, or one group will ask the TA a question and s/he'll give them the answer, and then another group s/he'll tell them to go research it or look it up. S/He's also very keen on what people need, which is good. If s/he feels like someone can figure it out by themselves it's better for them to figure it out by themselves.

Some students said that their TAs were not very effective at explaining complex concepts to them when they were having trouble understanding. A complaint about a particular TA was that "he just doesn't want to tell you" the answer:

S: I don't like my TA as much. I had a better TA last semester, sometimes I think that he knows a lot about chemistry, but he just doesn't want to tell you. Well, he just doesn't want to have tell us, he is a lot like professor Wright in that respect, he won't just tell us the answer.

I: He makes you fight for the answer.

S: Yeah, you have to find it yourself. So that is kind of like, oh, you know, you get frustrated again.

TAs sometimes had difficulty addressing problems in social dynamics. A student who described her group as having very poor dynamics, of which the TA was aware, said that her TA took a very hands-off approach to this problem:

S: ...I think he is trying to survive it also. He realizes that my group is really shitty....He doesn't really necessarily understand how to deal with it though. And since I haven't come directly to him for a solution of any kind, I think he's just kind of decided to back off and just, let it go it's course, I guess.

3. Patterns in student response.

3.1 Students using an individualistic approach adapted less well.

The individualistic approach is associated with a set of strategies that students often use to achieve success in traditional courses.

3.1.1 Skipping class and getting the material from the textbook and/or classmates' notes.

As one student who was doing poorly in the course explained, being absent from class was extremely harmful in this class as opposed to calculus class:

S1: I miss half of them [of the classes]

I: So you are not getting the links between one day to the next.

S1: Right. I 'm just a bad student...

I: Does that affect the way that you are learning in lab and doing homework and so forth.

S1: Well, pretty much. Well, yeah, of course it does because I wasn't in class.

I: Well, it varies because in some classes, people don't need to go to class.

S1: Well, right. Like last semester I didn't ever go to calculus lecture and I did fine in that class.

Another student who was doing poorly indicated that he had trouble with the problem sets because of not attending class:

S: Well, I don't know. I have, I have trouble doing the problem sets, because I like usually miss class like once a week. Because I like, I have to say oversleep. And ahh, so I have most of the time I have my lab partner helping me out on that. Just trying to explain how to do the stuff. So it, it's kind of helping, but not a whole lot. So I'm not actually doing it fully on my own and like looking everything up [in a book].

3.1.2 Dependence on TA to "tell us the real information" in discussion.

The following quote is from a student who, by her own estimation and by comparison to the class average, was not very successful in the course. She related that she expected to learn what she needed to know for the tests during the discussion section. Part of the issue was that she was not functioning well in her group, thus not utilizing the opportunity to discuss concepts with peers. And because she was in a quiz section with hour-long quizzes, she felt she had no opportunity to really discuss.

> S1: Yeah, what I know of discussion, the discussion section is the one that doesn't really fit. Because like, last semester, for 109, we, our discussion sections, that is where we actually learned something. Like the lectures he just babbled on about nonsense and then the TA would go into there and say, "Well, most of that wasn't important and isn't going to be on the test or anything," and he would tell us the real information. And that was like the important part. And, yeah we would have quizzes but we also had two discussion sections, which was really helpful. Here we only have one, and the whole thing is taken up by a quiz. And you never have time to discuss. And especially in a harder course like this, they should at least, since we have to put in so much work anyway, they might as well put in two discussion sections.

She went on to explain that she expected the TA to break down the complex material and present it to the students in a more simple form, but expectations were not being met.

3.1.3 Dynamics of individualism and dependence.

3.1.3.1 Problem-set homework.

The students who indicated that they preferred to work independently with the book and were having trouble with the course, also tended to say that they did not attend class faithfully. Thus, their difficulties with the course were intensified. One such student explained that it was not possible "to learn everything by doing the homework and looking it up in the book."

> S: Well normally for me in classes, I learn from doing the homework. That's how I've always like studied in the past and I've always learned everything by doing the homework and looking it up in the book and stuff, but, like, Dr. Wright gives us those, the ahh packets of questions instead of questions out of the book. So, a lot of times I can't..locate exactly what I need in the book. So and like I maybe missing the notes so then its kind of like really difficult to do the problem sets. So That's one of the reasons why I'm like really far behind in there.

The same student indicted a preference for working alone:

> S: I like working on my own more than I do working in groups. So, because I usually work better on my own. So I really don't like having to discuss things with people, I just like going through and doing it myself.

3.1.3.2 Take home exams.

Two students who reported attempting to do the take-home exams by themselves found them very difficult and did not do well:

> S1: ...I have only actually done work with others twice.
>
> *I: On?*
>
> S1: Like, ...only homework...So my take-home exams are really, really bad, because I don't understand the material real well to begin with.
>
> *I: So you did those by yourself.*
>
> S1: Right and that is like, it is impossible. Like the first two, I had a little help from my TA. But he is like, obviously he won't tell you the answers, and I still grasped the material. And even though I don't go to lecture, I do get all the notes, so
>
> *I: Now, you get the notes from the, from friends or something.*
>
> S1: Yeah from one of my friends. So I do kind of know what is going on. But...the take-home exams especially, they are really hard...Even, like, the exams that we have in class are much easier...

3.1.3.3 Labs.

The students who stood out in the interviews as the students who felt the least confident in their performance in Chem 110 related that they preferred the "cookbook labs" where the "steps were written down." In the first excerpt below, a student calls those labs, the "real" labs.

> S1: I like doing labs.
>
> *I: You like doing labs?*
>
> S1: I mean I like doing the individual. I don't like doing the group labs.
>
> S2: But the real labs, where they were written up in the lab book, those were fun. Because first of all it is not so hard. I mean sometimes they are more difficult when you have to do the calculations and things, but at least the steps are written down, and you know where you are going. And I really liked doing that because it is fun--mixing things and stuff like that.

I: And you actually get to do it.

S: Right, and understand fully what you are doing or at least you have more of an opportunity than in the group labs. [For the group labs] they just give you the open ended thing, like, "This is what you are trying to do. You figure out the steps to get there."

A few students indicated that in their group there were students who were the "brains"--those who did most of the conceptual work, and "gophers"--those who performed non-technical lab duties and had little understanding of the conceptual framework. These situations differed from situations where there was a division of labor, but all members of the group shared the goal of mutual understanding.

The two students who described their role as that of a "gopher" expressed low motivation to work in this course and participated less than their other group members. One student not actively involved in the conceptualization of the lab projects did more of the "setting stuff up."

S: Well at the beginning I did quite a bit of work and like..if I was just sitting they'd try to get me to do work like clean glassware and stuff. And like, well I set up the, the pH meter like every time that we worked on that because nobody else knows how to do that. So actually, I did get my fair share of participation in though. But like, more or less, it was like underground work on it all, and not actually the actual lab work. Just kind of setting stuff up.

This student was not learning much from the group lab experience:

I: Do you know...the logic of the group projects, why they're so...open-ended...?

S: Umm, because Dr. Wright wants us to be able to, like, actually experience what chemists do. Like for, in their actual jobs. Like, they don't actually go through a lab manual and like, "OK. What's the next step?" I guess they actually have to formulate a plan on their own. Like a plan of attack. And then follow through with that, and find like experimental errors and like fix it and then like redo it over. And...he wants us to get that hands-on experience like that.

I: Mmhm. And how much do you think that's happening?

S: Umm, well, it's actually..it is happening. Like I know, when we first get the ahh, little direction sheet of what the purpose of the lab is. I like kind of read through that and I think of...something that we may have to do and, like then like we talk it over with our lab partners and..so yeah, it actually has given hands-on experience. But, since I'm not doing the majority of the actual lab work of it, I'm not actually getting that full experience of it.

A few students said that in their groups the goal was to get the work done, not to come to mutual understanding of the material. Because of differing abilities, certain members of the group tended to do the brain work and others did the less-complicated lab work. At least one of these students was not comfortable with this approach, but settled for it, possibly due to the personalities in the group:

S1: ...it depended on who got the insight at what time. Rather than use the insight to kind of bring everyone up to speed, it would be the kind of thing that we could say, "OK, now we can race ahead to this step, since we've got this now."

I: It's just a get it done...kind of thing?

S1: Right, because, I mean, at this point we have a lab this week that's finishing up group lab, and we're running around like mad trying to finish it now.

I: So it's an issue of expediency rather than -

S1: Right. It's a matter of saying, "OK. Everybody think about this. The first person to get it will do it."

This student often settled for learning through an "overview" of the "genius's" work rather than an understanding:

S: ...what happened with our group a lot is we had a [student] who was a real genius in there, I'll admit. I mean this [student] knew what was going on. But what often happened in our group labs was that we would spend a lot of our time doing procedures in the lab itself, and then this [student], because - we were all constrained for time, but this [student] would often do the spreadsheets and so on, and s/he'd say, "Well, here's the spreadsheet." But obviously there's inherent, real difficult calculations in there that neither of us two ever saw. So we'd get a good grade on the group lab and everything, but I think the way I was learning through that was by an overview. I was saying, "OK. Here's the final write up. Here's what we saw," rather than the way I think it was supposed to be done. That is, "Here's the step by step. We're going to really piece through it."

I: So partially through the division of labor that happened, and partially because of the different levels coming in?

S1: Yeah. I mean, I'm okay with chemistry, but I'm not the kind of person that can walk down and see a gigantic problem and say, "Oh wow. OK, I know how to do this. Write it down," and you're done, because this [student] is that kind of person.

A student who was less motivated to work in this course also discuss a reliance on lab partners, "trusting that they knew" how to proceed:

S: Well..like our last lab, I well, like, I knew the basic purpose of it, and like, I knew the ideas that we had to follow through with. But then like actually, doing the actual work, like when you had to find the potential with relation to pH and stuff like with different concentrations, actually all that, I didn't know exactly...what different like numbers and stuff that we'd have to use. And like I just relied on my lab partners for that. Like trusting that they knew what, they knew exactly like what numbers and stuff to use.

Another student who was performing poorly in this course said there was one member of the group who "knew what was going on" and was the type that didn't like to explain anything:

S1: ...most of the time I don't know what is going on, especially like with the group projects. Because in my group there is only one person who does know what is going on. And s/he is the kind of person that doesn't like explaining anything. It is like, "That's what it is." And there is another [student] in my group. S/he is the one who mostly organizes it even though s/he doesn't always know what is going on. But if we didn't have him/her the whole thing would fall apart because s/he writes down anything and make sure we know everything that is going on. But if s/he doesn't understand something, the [person who understands] goes, "Well, if you don't understand, then I guess we are done for the day."

I: Then what?

S1: Then I guess we are done for the day.

This student did not perform experimental work and was asked to clean glass ware:

S: But basically [the other person who doesn't understand] and I, we mix the solutions and [the person who does understand] yells at us to clean all the glass-ware. And s/he doesn't actually do anything. S/he just tells us what to do.

I: What does [s/he] do?

S1: S/he has to do the titrating and calibrate the PH...It is just like, I am usually sitting there totally lost, and s/he goes, "Well, why don't you clean some glass-ware or something." It's like, "All right." And it ends up..., like last week...we were there for almost the full four hours, and all I was doing was cleaning glass-ware, drying them in the air-drier, coming back, "Here, clean this." Cleaning glass-ware, going back. It is like, "This is helping me learn chemistry?"

3.1.4 Cramming for exams.

Most students were involved in a continual process of preparation for the exam. The one student that reported cramming for the exam said that he "bombed out" and did not understand the questions:

> S: I had no idea what was going on in the exam.
>
> *I: So it was a bit of a surprise..that you didn't know, I mean you felt that you could get the average...*
>
> S: Yeah, I thought I basically [understood], like, I read the book, and, like, read my lab partner's notes and studied the questions and stuff. So, I had an understanding of what was going on, like, not real in-depth. But I had, like, ...broke the surface of the understanding. But like, it totally surprised me, like, the questions on there and like, not being able to understand, like, exactly what he was looking for.

3.1.5 Course is not for everyone.

At least two of the students who were doing very poorly in this course indicated that they felt that this course was not for everyone, that their needs would have been better met from a more traditional course. One of them stated:

> S1: Really I don't think that the class course really needs to be changed. I just think that people need to be warned better before the class begins, just as to exactly what it entails, because like if I would have known what the class would have been like before I signed up for it, I never would have signed up for it. I would have just went, "well, I can take 104 and get an A instead of taking 110, not understanding anything and getting a D. It's just a much better choice.

3.2 Students willing to use a social, work-it-out approach, adapted well and had a strong sense of accomplishment.

A social, work-it-out, approach was adopted by students who responded well to the demands of this course. These students tended to express the attitude that their group was not without problems, but that they all worked through them together toward a greater understanding.

> S: I liked my group a lot. And, I mean, in fact, I know that two of the three people in my group besides me are going to be in my Biocore lab next semester, and I'm hoping that we can work together because..I mean we didn't always get along, but we really liked pushed each other to like get stuff right and work hard and we made each other think so I thought it was easier to do.

I: So tell me about that, you didn't always get along and did...

S: Well I mean we, sometimes we'd be like you know, we'd be like arguing about who's right. And you know, we just we'd..fight it out, not fight but you know I mean like give our opinions until, until we could prove who was right or else we'd go to [the TA and ask] (laugh) "Who's right!?!" But I mean it was never like, we wanted to hit each other or something. (both laugh) It was, it was civil.

I: Well that's good.

S: But we were like testing each other's like knowledge and limits and so it was more learning rather than like one person taking over the group and saying, "Well I know how we should do this," and then everybody else just going, "Yeah! Right."

These students expressed enthusiasm and a sense of accomplishment, particularly with regard to the open-ended group lab projects.

S: I think its a really fulfilling class. I mean you get stuff done and you're like 'Yes! I got this done!' Because we're almost done with one of the group labs were working on, and I know that when we finish tonight after, you know I'm going to be like 'Yes! We finished this!', and it will make me feel like happy. So..it is a really fulfilling, when we finish things I always like, you know when I was done with my test, I'm like, you know, I feel like I've really accomplished something.

S: Yeah. I..I don't know what I'm going to end up with a grade for this class. I'm really praying for an AB but, umm, I don't know. I just, I've learned this semester! It's so neat!!! (both laugh) ...In high school everything was so easy, then I got here and I couldn't do anything. And now I'm feeling like I can do stuff again and my self-esteem is like out of the toilet. (both laugh)

The above student again makes the connection between the sense of accomplishment and the trial and error involved in the group labs:

S: [The group labs] are like, "Oh, might not work, but let's try it anyways." ...It can get frustrating if you have like more than one or two days in a row where you get absolutely nothing done. But, umm, it's pretty, it's kind of rewarding. It really is.

3.2.1 Interdependence and self-reliance.

Students who reported positive learning experiences through group work generally expressed that the members of their group were interdependent and yet ultimately self-reliant because they were tested individually on in-class exams.

One student points out the reason for this interdependence, comparing a former approach to group work, an individualistic one, to the Chem 110 experience where "if you don't work with other people, you don't even know where to start."

S: The other students have definitely helped a lot. There are a lot of things that I never thought--I never worked in groups before.. I never thought I could work with other people very well studying.

I: Why did you think that?

S: Well...I'm very impatient about things like that. And...usually I don't have the same, like, pattern of thinking that other people do, so even when they're trying to explain something to me--they'll just take a different path to get there than I normally would. And so I usually find it really tedious. It doesn't really help me. Normally, I always found that it didn't help me very much because I would just find my own way to get there anyway. And...also I don't like explaining things to other people...because I would explain it my way and it wouldn't make sense to them and it was just really hard for me, and then I'd get frustrated. And I was just really impatient that way. But then with this chemistry stuff, if you don't work with other people, you don't even know where to start. It's not even, like, how to get from one point to another, you don't know where you're starting from. So, it's that those people [in your group] that establish some sort of basis for you all to work with. Like the way that we always worked on our problem sets, like, well we usually work with a group of like 4-6 or maybe even 3 and we'll all sit down and all have our own papers and our own problem sets and then we'll do number one. And everyone looks at number one and does it as far as they can, and then once people can't do it anymore then people start asking questions.

3.2.2 Exam preparation a steady process.

Some students reported that they generally worked alone on the problem sets and then worked with the group on difficult areas or points of clarification. The student quoted below discussed this approach and indicates that this was an excellent way to really learn and prepare for the tests:

I: How do you normally do them, individually or with your group....?

S: ...If I try to work on them in a group, it doesn't usually work because, you know, you need to think about them by yourself first. Well I do, because if I just like listen to what the group is saying, then I forget to think on my own. (laugh) And so I'm just like, "Oh! That's a good idea!" And then I do it. So I usually try to do them myself first, and then when I have questions I'll go to other people that are working on them, and say, "Well how did you do this part?" and whatever and then they'll say, "Well, you know, what did you do for this?" and so I think that works better for me.

This student went on to say that it was important to be able to do the problems alone:

S: I mean the [homework] problems are pretty difficult...they're from old tests, so they're hard. (both laugh) And so...that's another reason why [I work individually first] because if you work on them by yourself, them I'm more like ready for the test I think. I'm like prepared to think that hard...[whereas] if you do it all in the group right away, I that I don't learn it as well.

Another student who first works alone on the homework, but mostly with the group, said that when she is stuck, usually a group member will have an idea. The student feels that a good understanding is possible through group work:

I: What gives you the most difficulty? You say you can't do certain little things here and there.

S: I think the hardest thing is like taking what he says in lecture. I can understand everything he says in lecture and you know, follow everything he is doing. And then applying it to a situation that I have never seen before. I have problems with that.

I: You mean in the group labs or in what?

S: Um, just on tests and homework and stuff. Sometimes I can get 'em, but sometimes he gives 'em like really hard problems and I just don't know what to do.

I: So what do you do?

S: Oh, we work in groups. Somebody will get an idea somewhere along the line.

I: So how much of it do you end up understanding?

S: I would say quite a lot of it. Because once you do a lot of it with your group, you don't just copy down their answers, and ask them how to do it. So.

I: So at this point of the course, which aspect of the course aspect, lab lecture and discussion and outside homework and that sort of thing. Which aspect is most important for you for actually learning chemistry.

S: Oh, I think probably doing the homework.

I: How come?

S: Well, without doing that you don't really get the concepts that he is saying. You watch him in class, and it is like watching a movie. Oh, yeah, that makes sense. And then you don't actually make yourself think about it until you do the homework. When you do the homework you suddenly realize, oh, this is how it relates to real life. I think, yeah, the homework is definitely the most important part.

I: And do you work on the homework in a group?

S: Usually, yeah. We'll try to work out a few problems before we meet, and then we will just sit and do the homework.

Several students indicated that they appreciated the fact that the last few lectures, although presenting somewhat new information, were not going to be tested on the final exam. This eliminated some of the pressure from students who felt they had already developed a cumulative understanding of the course concepts.

S1: What we are learning in lecture now, Wednesday, today, and Monday, Wednesday, Friday of next week, are like for your information lectures. We have to read a research paper and answer some questions on it, that deal with what we are learning in these lectures. But none of this is going to be on the final. So it is not, so I am not crammed at all. I can start studying right now for what is going to be on the final...

I: What is the impact with just having this information that is just for your information.

S1: It's a lot nicer than having to worry about having it being on the final. Having to learn it in the last week very well. It is kind of nice, it is not like they're slack lecture, where you don't have to worry at all about them, because we got the research paper today and it's due next Friday, the questions on it. And it's dealing with all the stuff we'll be learning in these lectures. It's just, I think it's a lot helpful, it's a lot nicer than going up right until the end.

3.2.3 Regular class attendance and being willing and able to learn by listening.

All of the students who reported feeling fairly successful in Chem 110 and having a fulfilling learning experience, attended class regularly.

I: Umm..so at this point in the course which of the [course components] ...is most important for you for learning Chemistry?

S: I wouldn't miss lecture. Like, I wouldn't skip lecture, if I could at all avoid it...unless there was some excruciatingly terrible..I mean I wouldn't just skip it like I might some other classes...

This student went further to relate that she prefers to listen and "absorb" rather than to learn from reading:

S: I don't know, we haven't used it a lot, but I don't mind because I don't usually like reading from the book that much. So, I mean I think its really cool that he taught us everything he wanted us to know. In class.

I: What difference does it make for you, when the emphasis is not on the book?

S: Well, I learn better by hearing, so its makes a big difference I think for me. Because that's why I can just listen in class and like learn a lot, so I mean, I learn a lot from reading too, but I learn a lot more just from hearing what people say and like, you know, I don't know, absorbing it, I guess, so..that was really good for me. I really, really like the way he teaches, its really active.

3.2.4 Labs.

3.2.4.1 Sense of accomplishment in group labs.

Most students did not mention the cookbook type labs in their second interviews, but instead expressed a sense of accomplishment from the group labs. One student related that the canned labs added little to her understanding, but group labs added much:

S: I don't think [lab] really adds to the understanding a lot in itself.

I: Would there be a way that it could, or do you find it...

S: Well, our group projects are I guess how it does. Like the canned labs, you know you have a procedure written out for you, and you have your purpose. (laugh) They tell you exactly what you need to do! But umm, like our group labs, we have to actually sit down and talk about what our goals are and how we think we can get there and then we try it, and then it doesn't work and then we try something new. So, I think the group labs are extremely helpful and I'm really glad that we did do those. I wish they hadn't have taken, I wish they would have been a little less intense.

I: Was there anything that you learned through the group work besides the content?

S: Umm..I don't know, I think, I mean I think we did discover things..you know I mean we'd be like working and we'd be like, "Oh. Well, how are we going to do this?," and we'd have to work it out.

3.2.4.2 Interdependence/self-reliance in functional work groups.

In groups that functioned well, students counted on each other to be there:

S: Yeah. I mean, I remember in - plus 109, you couldn't miss lab either, but it wasn't for the same reason you couldn't - like, I can't miss lab now because I'm like, I have to make it on time for lab because of my group. My group's going to be waiting for me and that's rude. But in 109 I'm like, I have to go to lab because they don't let you make up labs. If you miss a lab, you just get a zero, so it's kind of like, I have to go to discussion cause we're taking a quiz, you know.

I: But there is a group responsibility that you feel, is what I'm sensing.

S: Yeah. I feel it from my group. I mean, I have this - talking to other people, everyone in my group has that I think. It's really good, everyone is with us and everything. I've talked to people in other groups. Like, someone was telling me about some member of their group who goes every day at four o'clock. Like, they're working on their group project in their lab or whatever, and he gets up and he goes, it's four, I'm hungry, I'm going to go now - and he just gets up and goes! Every day at four, he's like, I'm hungry now, bye! (laughter) It's just the strangest thing! I couldn't imagine anyone doing that!

3.2.4.3 Equal participation.

In some groups, students felt that all group members contributed equally and that all opinions were valued and used. One student talked about her group's tendency to "fight it out" before coming to agreement:

S: ...We'd be like arguing about who's right. And...we'd..fight it out, not fight but you know I mean like give our opinions until, until we could prove who was right or else we'd go to John [the TA] [and say] (laugh) "Who's right!?!" But I mean...it was civil.

I: Well that's good.

S: But we were like testing each other's like knowledge and limits and so it was more learning rather than like one person taking over the group and saying, "Well I know how we should do this.," and then everybody else just going, "Yeah! Right."

When students said that there was equality in the groups they tended to say that they liked the members of their group. They also tended to say that they felt that this equality was made possible by the fact that all of the group members were interested in learning the content linked to the group projects:

I: So all the members of the group [contributed equally]...

S: Yeah, surprisingly. I was really scared in the beginning of the semester about group work. Because that doesn't usually happen. So I was really, because all four of us really wanted to learn the stuff.

3.2.4.4 Each member learns everything.

Some groups used a system of division of labor with some of the group members working on the computer spreadsheets and others working on the in-lab experiments. The students who reported that this was an effective way to learn emphasized that even though the work was divided, their group strove to understand all aspects of the lab.

S3: I like - maybe our group was a little more integrated, but we tend to - there were a couple of guys who did more lab stuff, and some other people would do more theory stuff, but we all worked together on it. They'd come up and then explain it to the other group, the other half of us, so that worked out real well for us. I think we all understood everything a lot better...I was usually kind of the lab guy...it was just like there were a couple of us that were just better at it than others, and the others were better at the theory stuff. It just worked better and easier if we did it that way and explained how we did everything later.

I: Do you think that's optimal for your learning? What do you think?

S3: I think it was optimal for the group project, and the way we did it, I think it was optimal for learning too, because it wasn't just, okay, I did it here it is. It was, I did it, and now this is how I did it, and then do you understand how I did it?

I: Okay, so you strove to have every group member understand at the end?

S3: Yeah. I mean, there was a genuine concern that everyone understood it.

S: Um, well! I don't know! Um, for this second project that we are doing, we like split up into two groups. Like, two are the members of our group doing the calculation, and two others including me and my other partner do the experimental job. So, I think we can speed up that way. I don't know!

I: So you intentionally tried to divide the group up so that way you could accelerate the process?

S: Right. And after that, we meet together and discuss what we are doing so far, and then, like try to switch, you know. Like me and my partner do the calculation and then the other two partner of us do the experimental job...and see if we understand each other. And that's--yeah, that's probably what makes us want to divide the group.

3.2.4.5 Goal-focused open-ended labs develop individual and group problem-solving ability.

As the female student quoted below states, students were expected to "work it out," and they were successful:

I: Was there anything that you learned through the group work besides the content?

S: Umm..I don't know, I think, I mean I think we did discover things...I mean, we'd be like working and we'd be like, "Oh. Well, how are we going to do this?" And we'd have to work it out.

Some students said that they had learned that science involves extensive "failed testing" before "getting it right."

I: So what was it like in the group labs, starting out generally where you had a goal, but you didn't know exactly how to get there? What was that like?

S1: Oh, a lot of failed testing, You just have to keep on working to try to find out what is wrong with it. As you go, you find more and more reasons why it is not working in correct form, and eventually it starts working better. You test it...Really, I think the group projects helped a lot. Like I said last time, it is more like a real lab setting.

This student went on to say that Prof. Wright had spend considerable class time talking about this aspect of research:

S: ...the main thing he was getting at [was that] when you're in an actual laboratory experiment or you're doing research, almost 100% of the time, it's never going to come out the first time. You have to keep on. You do it once, and you learn things from that. You gain insights, as to how the solution, or whatever you're working on is actually working, and what's in it. And you correct for it. And, as you go along, you learn more about it. And it starts to work out better.

Although students are not told "how" to do the lab, they are given a very clear goal and a challenge level that is not so low that students lose interest and not so high they give up. The following student is discussing what to do if she found an unknown liquid in her basement:

S: I've always hated unknown labs.

I: Oh really?...Why do you hate them?

S: I don't know. They always seem, they're very overwhelming. You know, it could be anything! So it's, kind of, we did do a couple of unknown labs this semester. At least one that I can think of right now and I think there might have been another one. Umm...I did OK on it, but, we certain things to pick from. You know and it was..you could research, but if I had no clue what it was, you know, if it could be anything..I probably wouldn't [try to determine what a completely unknown liquid was]! (both laugh) But if I knew it was either this, or this, or this, ...I could, I would probably be interested enough to say, "Well now which one is it?"

I: How have your group projects been in comparison to that?

S: Umm, we usually have like a goal. So...

I: You know where you're working toward, you just don't necessarily know how to get there.

S: Yeah, definitely. We don't know how to get there! (both laugh) I mean that's the thing. We can usually get there anyway we want. It's just the goal is the object, so, and that's fun. Actually. Where we say, "Now what are we going to use?" But if you gave me a bunch of things and didn't give me a goal, I don't think (both laugh) it could be very happy. So I like the idea of knowing where you're going more than..just nothing out there.

3.2.5 Dynamics of dysfunctional work groups.

At the beginning of the semester several students related having problems with their groups. At least one of the group got better, but the others may have gotten worse as the semester progressed. One student in particular had great difficulties with the group:

S: Umm, well, like specifically last Wednesday, this Wednesday, two days ago. Umm, it was just a stupid thing. It was like, we had to do these calculations for this lab and it took like two hours to do. And the other two members of my group did them together. And I did them by myself because we didn't have to do them together. And, they had switched a data point, and had opted not to tell me.

I: Switched it, what do you mean?

S: Well, it's hard to say if they just decided to fudge their data, or if I had actually copied it down wrong. I don't know. I think I copied it down wrong, but I can't really be sure. Umm, but so I had the wrong data and I ended up with a much lower lab grade. And so my TA came over and yelled at them for like ten minutes. (laugh) And then I started crying. Because I have to redo all the calculations anyway, even though it was their fault. And I really don't have two hours right now to spare and it was just really frustrating. And the fact that they were totally nonchalant about it like, you know, "Oh, well. It's her problem. Not ours." Just kind of ticked me off, so...

In the midst of many functioning groups, the above student feels very alone:

S: ...I know I'm not the only person who's having such a crappy time with their lab group, but sometimes I just feel so alone. (laugh) ...

I: So umm, I think one other thing that you mentioned was that sometimes they would be sort of ahead of you and understand things and you didn't want to ask...how has that been going? What happens...

S: Oh, the same. Same thing. Umm, and even when I do understand it, and I try to correct like something they have wrong. This is another thing that happened. They just, they totally ride me about it. They say I'm so wrong, and blah, blah, blah.

The above student often worked alone because of personality conflicts with the group members. The student felt successful in the class.

S: Umm..I usually just, I do a lot of the group work that we're supposed to be doing together, I end up doing myself. Which is kind of a pain because I'm doing a lot more work than they are right now. But I don't have to deal with them. And its just nice for my sanity. So, I guess I've just kind of adjusted by isolating myself from them. Which isn't necessarily the best thing but, I just am tired of dealing.

This student learned to be self-reliant during the course, and described an assignment done without relying on the TA's procedure:

S: ...it could have gone a lot bad, a lot worse because I could have just gone home and copied it down, and it wouldn't have added to my understanding at all and I wouldn't have, come away learning anything. But I put the sheets away and like worked it out anyway.

I: Do you think you might have done that last semester?

S: Mm.Mm. No way! Well actually last semester, my TA was always about a week behind the other TAs. So we would have answer sheets handed out in class before our assignment was due. Because it was like a mass lecture and the assignment was from the professor. And so the professor would hand out the answer sheets but ours weren't due yet. So I would take that thing and I'd be like 'Oh so that's how you do that?!', and write it down. I didn't learn anything and I think it was definitely reflected in my grade.

The following student may have been forced out of the group due to personality conflicts. He works alone now and feels better prepared for the tests, but "got more done" when he was in the group:

S1: I found what was really getting material learned for me was doing problem sets and interpreting lectures mostly. Part of the problem sets, it helped a lot when I was in a group, but I usually didn't have that available to me. That's just something that happened. It was kind of unfortunate because I was seeing that when I was in a group I was getting a lot more done, but for sure I'd say in terms of learning the material the problem sets were indispensable. I mean, I was learning more for that, for midterms, than anything else, because they gave you an idea of what was on them.

I: You've been working by yourself pretty much? Is that how you ended up doing it?

S: I'd say probably 80-20 working by myself.

This student goes on to say that he felt very prepared for the exams by his solo work:

S: ...when I did - this might have had something to do with the way I was doing problem sets, but I was doing the majority of the problem sets, like I said, about 80% either on my own or with my TA, and when I actually got into the test, I found that in some cases they were comparable or sometimes even a little bit easier than what I was seeing in problem sets because they're so involved, and you know that in a test, I mean, they have a time constraint. I found that usually the exams were pretty comparable to what it was on a typical problem set.

One of the above students wanted to switch groups, but couldn't. The student thinks a process for doing this should be developed:

I: ...you were thinking about getting switched out at one point, what happened with that?

S: Yeah. Umm, nothing actually. I just decided, well actually, there's a slight problem. Umm, I guess what they were doing for switching groups was is if you were in a group of four, you could go to a group of three. And just switch groups. Because all the groups have either three or four members. But I'm in a group of three, so if I left my group of three there would be two. So, I didn't actually approach Professor Wright about it, but I just assumed that, it would be too difficult. And..but I've survived. (laugh) We, we still don't get along or anything, but...I guess [Prof Wright arranged the groups] the best way he could. I just think that he needs to ahh, reevaluate, umm, group changing and maybe like ask, maybe like have, individual interviews with people of a group and just say, 'How are you doing?' Because when we sit down as a group with him and talk I obviously can't say (laugh) 'I'm having a horrible time with my group, please get me out of it.' But umm, I think, I know it would be a lot of work for him to sit down with 110 people and say 'How are you doing?', but I think it really might help.

This same student did not pursue changing groups because of being in the same program for many years to come with the people in the group:

S: ...for one thing these two people are in a program that I'm in, so I going to be running in to them for the next eight years. And I just really, really don't like people to hate me. (laugh)

3.2.6 Perceptions of worth.

The issue of whether the volume of work in Chem 110 was worth what students got from the course did not arise in all interviews, and is therefore difficult to quantify. Varied responses are presented below.

Some students did not feel the course was worth the hard work. These students tended to say that they did not know "why they really needed to know this stuff," as they were not intending to become chemists.

S: ...I know I spend a lot of time in 110, I mean a lot of time. I don't know if I'd say it's necessarily worth it because I don't know how much--I actually don't know how much it's [chemistry content] going to help me. I don't know if I really need to know this stuff as well as I do. I don't know exactly what purpose chemistry is going to serve for me. Maybe if I knew I was going to be a chemical engineer or something and I had to know this stuff, then it would definitely be worth my time. I guess as far as going on in chemistry--cause I'm going to take more chemistry classes. Next semester, or whatever, I'll take organic. As far as that's concerned, I'm sure chem 110 will help me in my future chemistry classes. I'm not sure how much chemistry is worth my time, period, so I don't know -

I: So if a friend were to ask you, is it worth all the time that you spend on chem 110?

S: You know, ...I am really not sure if it was for me. Just because I am not interested in chemistry, I am not planning on perusing this any way. In fact, as soon as I can get out of chemistry, I am gone...We did learn a lot...And it was good to like know what you're doing and have done in a different way. But,...it seems like an awful lot of time spent taken away from other classes, that I actually like, you know, and care about...

I: What do you dislike so much about chemistry?

S: I am not really sure. It doesn't seem to have any relevance, or any. I don't know. When I am doing the problems, It just doesn't like make sense why you'd be doing this. Or, who cares? (laughs) I don't know. It just doesn't interest me at all...[Biological science] just seems more practical or more useful...I am just more interested in how living things work (pause) how they relate with each other. And chemistry doesn't seem to have anything to do with that... He [Wright] relates it some times. Like you know, he says some times, "If your

PH gets... two-tenths off, in either direction, you are going to die because of your blood stream." ...And you're like, "Hey, that's kinda neat." Ya know. And then you think, "Oh, chemistry does relate to real life."

Other students expressed that the time spent working on Chem 110 was "worth it." One student did well in the class and had truly come to understand the content. The student is planning on a chem-related major.

I: If a friend asked you if it was worth all the time that you spent...

S: I would say 'Yes.' Definitely. I think that I'd spend like all of it.

A student who does not plan on using the material in the future felt very good about this class:

S: Umm, I think its the time that we've dedicated to it, like last semester if I spent two hours on a homework I would think that I was overextending myself. But now this semester, like ten hours on something doesn't seem that major. So, it's time and time and time and time and it really..I guess it does pay off! They were right! (both laugh)

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Wright Lecture: From the TA's Point of View

Note: Due to time constraints, the researchers achieved less closure in analyzing the teaching assistant interviews than in the student interviews.

1. Teaching goal and teaching strategies

The TA goals for students in Chem 110 included shoring-up any weaknesses in understanding the course material, providing time in discussion to work on homework problems, ask questions about lab difficulties, perform group work, and relieving stress and frustrations. Quizzes were a primary focus of most TAs.

> R: ...I don't intend discussion section to be another stressful [thing]. To me that's a place where you shore-up all the weaknesses that you have along the way and so my quizzes reflect that. They're not real difficult but they do require that you know the material...
>
> *I: ...And your discussion section, do you see any development there?*
>
> R: Discussion section actually goes well now. Everybody has learned the pattern of, of how we are going to do things and it seems to be one that they like a lot. We're doing the quiz. We don't spend much time on the quiz...
>
> *I: OK. How long?*
>
> R: I like to give them 10 to 15 minutes. If it's a more challenging quiz, I'll give them 20 minutes, but most people can get it done in 10. They work in groups. Sometimes I have them work in their lab groups and sometimes I have them mix-up and just be in any group they want. I never really pick groups for them but I try to encourage everybody to be in a group. The people that worked alone I noticed missed things and people that work in groups get it all right. It seems like what one person lacks the other one knows and so they work it out. But we do that for about 10 to 15 minutes. If they felt the quiz was difficult enough that they want to see the answers we'll work on the answers. I'll have someone from each group come up and put up an answer. If not, we'll just move on to general question and answer on homework problems or lab difficulties they are having--anything that they need to work on. It's working really well I think. It allows them the time that they need to ask questions. Office hours are there for that as well, they're required to come to discussion section, so they're there anyway and they are able to ask questions.

Another TA stated that he determined through quizzes that students were not "up to speed on the material" and he had difficulty adjusting the quizzes to their knowledge level.

R: I started out by giving quizzes and then going over those, but those didn't seem to go over so well. So basically I started to just pass out questions and have the students work on those as a group immediately for 20 or 30 minutes. Then we would present the answers. I think what happened is a lot of the students were just not up to speed on the material and so the quizzes were just a little too difficult for them. The other thing is it was hard to judge exactly how much material I could fit in for a given period. Some days I'd end up overloading the students with a particular set of questions and other days it would seems little laid back and there was more than enough time to complete the questions that I had given them...The format [for discussion] was I would pass out a sheet of questions, and the students could divide up into three, four, or five groups and work on it amongst themselves. While they were working on it, I would assign a scribe and a spokesperson and a leader for each group. And then, depending on circumstances, we'd have spokes people come up and present their answers to the class. We'd have spokes people explain the answers and we'd have the scribes turn in a group worksheet with the written answer as to what they had accomplished.

Finding informally established groups ineffective for discussion quizzes, this TA's randomly assigned students to groups for more effective group learning on quizzes.

R: ...When I originally started out, I was having students work on problems in groups that they would just sort of form on their own. That didn't work very well. What started to happen was they eventually made one large conglomerate group. Then a few people would tend to sit on the outside of the class. So what I started doing was having them hand off just as you would do in gym class in grade school...so they would be kind of randomly assigned into groups that way. That went pretty well. I did ask them if they would rather work in the lab groups to do the problems, but they prefer it this way so they could work with other people.

2. TA perception of their roles: facilitators

As Teaching Assistants for Chem 110, some TAs had to make the switch from the lecturing model of "Telling Students How" to the guidance model of "Asking Students Why". One TA expressed this perception of his role as "becoming the idea man verses the answer man."

R: Yeah, I've backed off quite a bit more...I talked before how I used to go around and I'd try to lead them through it and give them the help if they needed it. I've been able to back off on the more obvious "This is the answer," help. I've backed off even more to leading questions...When they ask me questions, I think we've developed a rapport now where I can flat out tell them, "I don't know." Sometimes, with TAs, there is a tendency to not want to tell your students that you don't know [the answer] for fear of lack of respect. And I think we've developed a rapport. I can say "No, I don't know what is in your solution. I can give you scenarios [of] what might be in there and you can think for yourself. Try to think through them and figure out which one you think is the best." So I'm the idea man, I guess, but I'm not the answer man at all.

I: Oh, and you feel the students are comfortable with that?

R: Well, where some would like the answer, I think most of them know that that's the way the course is supposed to work anyway. I've told them enough times. I've flat out told them that "I'm not going to give you the answer," [even] if I was hounded long enough. And so I think they're comfortable with it. I give them the scenarios and they think about it and talk to each other. I don't think its a big problem. I don't think it's a problem at all. I think it's actually a good thing...I've told them several times, or some people have come up and teased when I kept asking them questions. One of them was saying this in all joking, was like, "[TA name] I don't want to learn anything I just want to get the answer!" (laughing) And she was saying it joking cause she knew exactly what I was doing...

Another TA talks about being a facilitator for the students and relates that this role enables him to utilize his strong research background.

R: I try to facilitate certain things-- [guide] them in certain directions in their performance, but I also lay back and let them--they are the masters of their fate, and I'm just there at times to guide them and make sure that they're thinking about the right things. If something doesn't go right or if it goes right, "What does that mean? What's the next step then?"

I: Where did you develop this method?

R: In part I think it's the group dynamic. It's the groups, and you modify or adapt based on the environment that you're given. We were given a group teaching environment, so we have to adjust to that, in a way. Also, I don't know if it was ever explicitly stated in any discussions with Dr. Wright or the other TA's in our group meetings or not, about what we do or don't give them, but I've never given them an answer to a question.

I: So this wasn't something that Wright said to you?

R: Not that I recall. Maybe, but just the impression I'm under, that they essentially need to turn in their outcome, and we're just there to facilitate. I may be wrong on that perception, but that's how I perceived it.

I: How does that - how do you feel about giving that all over to the students?

R: I think it's great, cause then it's up to them whether they pass or fail, or how well they succeed I should say. So I like it. I'd rather be there as a resource person. In [another department] when I was TAing there or when I was teaching some of the undergraduate classes, I probably had a fairly similar style as well... I don't say, "This is the answer, and how do you go back to getting that right answer." It's always a process involved... I'm just there as a resource person for them. I just go around from group to group as I always have and ask them what they're doing and what they think about what they're doing, what is happening while they're doing something. While I'm observing, if I see something happening, see if they notice that and what they think it might be due to, and where they think they need to go next...This is a nice experience, cause in part if frees me up, cause I don't have to be some god of chemistry, which is good because it would demand too much of me and I wouldn't be as effective then... So this really utilizes my talents and abilities cause I can know how to think chemically, you might say, and what to look for, cause I have a strong research background and also some--I understand what the students go through cause I've been there--it hasn't been that long--and I know what didn't work for me... I like the system here. I think it's a good way to go about it.

A third TA discussed his process of dialogue with the students.

R: ...I'm still trying to act more as a facilitator and as a guide rather than as a, shall we say, someone that babysits the lab or someone that just hands out answers on a silver platter...I think this is the first time that I've probably been justified [in using the method] with Professor Wright's own style of inquiry and his teaching method. In the past it's been more, "I'll still try an aristocratic method of questioning," but usually I'll end up explaining things flat out near the end . . . I just think you kind of have to just judge each student on a case by case basis. Obviously if they have such fundamental deficiencies that they won't be able to make the leap that they need to make, then it's time to sit down, and explain things on the chalkboard. And go back over the basics and then kind of lead them through where they needed to be... I find that I end up doing it maybe once or twice a lab period. A lot of times those students' questions will be, "This is what we did, what do you think?" Then I'll mull it over for a couple of seconds and spit out my own personal impression, and they'll think about it, and, "Yeah, I guess that makes sense." Or then they'll point out something that they had already thought of that perhaps I didn't take into account. So we'll kind of dialogue back and forth in that respect.

2.1 Issues of concern

Several TAs experienced difficulties adapting to the role of facilitator. The following two quotes illustrate this point.

R: I wasn't really quite sure how to approach in the lab, with the group projects, how to approach that as far as how much information I should just give the students and how much I should let them just go off on their own and work it out themselves. When we did course project, I think I erred on the side of not telling them. . . . Before it was trying to teach them lab technique. ...But this half of the semester stress research type situations. So before the

TA's standing over a student and telling them exactly what to do. Now, the TA is standing back and letting the students use what they have learned and try to solve the problem that they have. So, it is different.

I: OK. How natural is that for you to be in that role?

R: Not very. It is a lot more natural to say "You want to do this instead," or "don't do that. It is easier if you do this. This is more efficient, will get you better results." And now [when they say,] they have these "We're thinking about using this technique and you are thinking, "Well, that is not going to work as well, but I can't tell them that." I can only say, "Well, that should work." And it probably will, but maybe not as well as something else, so you kind of have to keep your opinions to yourself. But then explore it on their own. That's tough from a teaching point of view I think.

A few TAs were dealing with adaptation issues associated with the complexity of social dynamics that come with using cooperative learning methods.

R: Well, having to worry about student-student problems, and especially if I teach for Wright again, he will use the group thing again I am sure. And, you know, the one with the sexual harassment group, and the other group where the people are back-stabbing each other. And other groups where they are just so social that they don't get any work done. I don't know. How do you go up to someone, and tell them "You are not working hard enough, you are talking too much. Get back to work." I think that they would resent that type of comment... Even if they did half the work in this class it is probably more than any other class that they are taking right now. So, I am sure they would probably get some resentment out of that, regardless. And also, having to say, well, with that sexual-harassment group; when the TA brought them in to talk to Wright. They didn't realize what they were doing. The effect that their comments had on that other girl. When I talked to the TA about it, and they felt very badly about that. But they still removed her from the group, and made another group out of those guys. Um, I don't know. It would be nice if you don't have to deal with people. I mean it sounds bad, but, on a personal level, simply because, that is their own business; I am just here to teach them chemistry. And maybe that is not a good attitude.

2.2 Effect of professor's structure on TA role

Some TAs noted the influence Wright had on the understanding of their roles and teaching approaches.

R: It's really quite different, but anyway. Obviously Dr. Wright has a certain approach that he wants taken in lecture and in lab. Working in the groups has a major affect on how you interact with students and how you approach certain problems. So yeah, I think he's probably the main catalyst for whatever style we've had to adopt to help our students, definitely.

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Another TA notes that Wright is very confident in his teaching method.

R: Oh, Dr. Wright...I think he's very confident in the way that he is teaching and so he tends not to change. The students have the board of directors that are allowed to make suggestions and I think he listens to them and I don't think they've have made very many drastic changes or anything like that.

One TA consciously employs a modified "authority figure" role in the group setting by "forcing the students to make decisions."

R: Because it is their project and they are the ones who made the decisions on what to do and everything like that. And I just forced them to make that decision because I was standing there, the "authority figure," saying "All right, well what are you going to do?" So it was a structure in that it was a set time for them to do this. But, it was not a structure in that I didn't tell them what to do, I just allowed them to make a decision.

2.3 Varied perception on instructor/TA effect

Several TA perceive their role as teaching assistants as having a greater influence on students than the professor. The TA comments that:

R: Yeah. I suspect that the TA's have a lot to do with how the students learn simply because they are the ones that are in contact with the students more than the professor. Maybe I have a too self-important egotistical opinion here, but I think the TA's do have more of an impact than, say the professor. Particularly all of the lab stuff. And we talk with these group projects.

Another TA expressed doubt about a TA's ability to "make or break" a student's chances of success in this course because, unlike TA behavior in more traditional courses, he "doesn't give them answers."

R: ...I don't know if the TA makes or breaks here, as opposed to other courses, cause I don't give them answers. I will say, "Think about it in this way or approach it from this direction." I don't know if they realize that's probably what other TAs do too. At least, I think that's what the other TAs do, but I won't give them answers. I will help them learn the way, and I don't know if they perceive that as hurting their chances at improving their understanding in class. I don't know what the rankings are between different sections as far as the grade distributions, so I don't know. Hopefully I'm not making a difference. So as far as TAs - as far as the students themselves, I don't know. If I had a different class, they'd probably perform differently.

3. The dynamics of teamwork

TAs note that difficult, open-ended research problems plays a critical role in setting the framework in which teamwork dynamics develop.

3.1 High work load forces cooperation between students in groups.

Many TAs noted that added pressure and time constraints forced students to allocate duties, to manage time effectively, and to work together.

> R: On the whole, group learning is good because the relation I've seen between the students. This is a point of opinion. Students have learned with the added pressure and the time constraints. They've learned how to manage their time and allocate duties to different people and that requires cooperation definitely. And some groups that really works well. Others haven't learned it quite as well.

> R: The things that have helped them do group work is...the fact that the load had been high they've had to work on it to be able to work together...that's a definite pressure that's forced them to enhance their group work...Right, you have to have connections. You have to have friends that you can talk to. People that are studying the same thing that you are. Of course you ask them questions, see if they have done it first. You don't want to repeat their mistakes. You have to use your buddies. That is a real life consideration. It is not fair sometimes but that is just the way it is. Maybe that's a good thing or bad thing depending on how you want to look at it. In this situation, since it is more academic, I think they should have that information available to everyone.

3.2 Research-oriented projects demonstrate to students the "nature of science."

Many TAs related that the students were learning the processes of research. They noted that along with came frustration.

> R: The idea of the great project without all set procedures, all that in laboratory--I thought those were very good ideas right from the start...I was hoping to see [how well the students did from] where the students will just sit there [and] be completely dumb founded by this idea of "Well, how [do] I approach a problem where they haven't told me what to do." And they really worked through a lot of the same sorts of steps and feeling that I have seen working as graduate student, where you are really clue-less and completely frustrated and don't understand what is going on. But then as you continue to just get over it and keep working on it, you begin to see the light and are able to achieve your goal which is much more valuable, use of your time then simply going in to the lab and doing experiments which are just to teach you one, certain skill. So, I those I think have turned out quite well, so.

Student experience of high levels of frustration and of not knowing the right answer while learning the process of working in a group

R: I think it shows them that there is not a set answer to a lot of the problems that we get in laboratory. At the same time, I think it demonstrates to them the nature of science, and that we're not trying to find a canned answer that's either right or wrong. Rather, we're going after the process and trying to elucidate what's going on in the system. People just may not know, and you have to live with that uncertainty.

I: How do the students react to that?

R: They don't like it. They don't. They want closure for their experiments, and they want to be able to arrive at definitive conclusions from their experiments.

I: Has that changed over the semester, or has that been pretty constant?

R: I think students are kind of growing to expect that. I still think they get frustrated when they can't get data that matches their expectations.

As many TAs did, this TA reflected on his/her personal experience to understand the students' frustration with open-ended problems.

R: I think they get a better idea of what it is really like trying to solve a problem. You don't come up with the right answer the first time. With a complex problem, you will find that the things involved are more complex than you thought. When you came into this problem, you thought, "Oh, this is simple. We do this, this changes and then we measure that." And than they start doing that and they find, "Oh, I forgot about activity coefficients. Oh, I forgot about dilution effects." Or "I forgot about this or that." And they realize that it is a really complex problem. And it is not as simple and straightforward as they thought. And they really have to think about what is going on and understand it.

I: Do you think that the students are adjusting to that? I mean, I am sure this is relatively new for most of these students.

R: I am sure it is. I think that they are doing well. I am not sure. I kind of think back to my undergraduate education and it was nothing like this. I didn't start doing independent research until I was a senior. [It] wasn't really independent. I was under a professor, of course, but at least it was somewhat similar. So, I think that it is good for them to really see what it is like now, before they have dedicated themselves to one particular discipline or another, and find out what it is really like, when you get to the level they will be at when they graduate, say. So, this, I think is reflective of what it is really like out there.

3.3 It is good to be able to both work alone and in a group.

However advantageous group work is, several TA's still believe that it is good to be able to work alone.

R: I think that's pretty good. If you establish a group of friends who you work well with and can accomplish things with--I think that's very beneficial. I know when I was a student there are times when I worked best alone, but there are times when I worked best in groups, and it's nice to be able to know that you have a group that you can work with effectively.

3.4 Group dynamics overall

3.4.1 Time management a necessary skill

As stated in comments above, several TA's note that group work requires a great deal of time and commitment. As a result, students are challenged to set priorities and better manage their time.

R: I think you get a group of students in and you see that they do try, and this course does demand a lot of time for them, which takes away from other courses. So there's a trade off there. If they spend too much time to get a really good grade or really understand it, then other classes sacrifice. And if they back off a little bit on the time commitment, they are not going to make as good of a grade or understand it as well.

I: What do you think about that?

R: Life is a series of challenges or decisions and priority ranking. This is part of that process. They have to find what they are happy with or the happy medium--what they feel is best for them.

I: Do you think they understand that?

R: I think they do now. I think, in part, they were forced into it [by] just the way school is. When I was an undergraduate, I went through the same thing, too. Certain classes have priority and you find out--usually one class dominates--and then the other classes are less important. But they do have their hierarchy as well...In each of the groups--each of the TA's are doing this--getting the groups individually and talking with them for a little while, 20 to 30 minutes, to see what they've done and "Why are we doing this?" and "What have you done to accomplish this goal?" "What do you think you need to do?" " What does the data that you've gathered already tell you?" et cetera. And you can see them thinking about it and stuff, it's good.

I: Yeah, it must be kind of exciting.

R: Yeah, and I think the pressure's off them a little bit because they don't have to get a right or wrong, an absolute answer. It's more an explanation for the process that was going on.

Another TA recounted her/his approach to helping students better manage their time and set project priorities.

R: ...I noticed...their approach didn't seem very focused. And they were just kind of sitting there wondering what was going on and not really knowing what to do. So when it came time for the next project, what I did was, I instituted a thing where I would have each group meet with me each lab period during the first part of the project. I guess I met with each one for twenty minutes. The first time that we sat down, I copied the calendar out of my date book and I wrote down "Well, here is today, and here is all of the different dates that we have to work on this and this is when your write-up is due." So, I asked them, "All right, what is your idea for what you are going to do? And what are you going to do about it today, and what are you going to do about it next period." And just kind of used that to focus them to be a little more task oriented and focused on a task. And said "Well, this is the big picture." Because I had asked them "Well, what is your overall goal?" And then back down to the little picture, "What are you going to do about it today?" And then, of course during the course of the discussion, all of the questions that they had about things they weren't sure about...we discussed the nitty-gritty details as far as what is going on as well.

3.4.2 A multi-cellular organism

The power of group dynamics over students' experiences in Chem 110 was observed by several TAs. The following quote vividly describes the affects of group dynamics as described by several TAs.

R: Most of the interaction I see is positive. They talk...they have a division of labor, so each time - and they kind of rotate a little bit.

I: Is it a healthy division of labor?

R: I think so. In most groups there's no clear leader or person who does the bulk of the work and everyone else just slacks off and doesn't do anything. I think for most groups everyone takes their responsibility seriously, and they do rotate jobs or positions. But there are clearly people who have certain strengths that others don't, so they take over a certain area. I have one group where there's a person who likes the computer, he likes to do the modeling, so they allow him to do most of that. Now they're all in there working together, but he'll have formed the basis of a model, and they all go in there together and revise if or do whatever they need to make it work. So yeah, they do take it from his cue, but he does all the preliminary stuff cause that's what he loves to do. I like that. Now there's also, when you work in groups, behavior that is reinforced, negative and positive, so if no one feels like working, no one does, kind of thing, whereas if they're all hot on it, or something like that, and want to get going, they all will. So they get this group dynamic type thing where it's a living, breathing organism, and some days they have a bad day. Some days they have a good day, and it's reinforcing too. If one person woke up, [and] they were having a kind of bad day, no one really stands up and says, "Well, sorry, we got to do this." They kind of all start saying, "Yeah, we're having a bad day, let's take off," or something like that. So they're a multi-cellular organism working--

I: They're no longer people.

R: That's right. So I think they're really learning how to interact with other people. Maybe in high school they didn't do this so much, and they're finding out how to work with other people. I don't know if that's going to help them in other classes, except maybe outside of the class. I don't know if other classes are designed where they can work in groups like this, but at least if they do have some more classes, they know they can work with each other outside of class to help answer problems associated with that class.

Another TA made similar remarks.

R: One of the detriments that I see to group work, which I really don't know how it can be avoided, is that the situation that you are in depends on who is in your group. If you have a group that works, people are able to work together, and work well together, than it's great for you. If you are in a group that doesn't work well together than it can be very bad. And it's pretty much random how the students are assigned. And they are assigned so they have no say in what group they are in. They just have to live with that. I suppose if you are trying to reproduce what it is like in the so-called real world, than that is the way that it is there too. But it is something that I don't know how to deal with. I thought but I couldn't come up with any answers.

3.5 Intra- and inter-group cooperation.

3.5.1 Intra-group: division of labor had both positive and negative aspects

TAs expressed pros and cons about the division of labor in group work. The first quote illustrates some of the cons.

I: Do you have concerns that in the long run some students will be missing...?

R: Yeah, I suppose that the experimental part isn't that hard to understand. It is the time involved in doing it. So, the people that are doing the spread-sheets probably won't have a problem with the experimental stuff. The people doing the experimental stuff, may not have a good understanding of the spread-sheet. That is a problem, because now they are being pushed experimental and not getting any of the theoretical. So that probably is a little bit of a problem. . . . As far as I know, there is a review with each group with Professor Wright. We ask them questions, but the people that did all the spread-sheet can answer all the questions on that, and the people that did the experiments can answer all the questions on the experimental part. I suppose that if Wright had meetings with individual students it would be better. But it would be too time-consuming for students. With twenty minutes a piece, it is going to take awhile.

Another TA spoke of the teamwork dynamics and division of labor and issue of maximizing learning for all members of a group. He felt that the division of labor was mostly positive.

I: But it's like they've learned sort of basic principles of team work or something...

R: Yeah, exactly. They are working as a team. There is one group that still isn't really working as a team, they do things one at a time. One person will titrate, two will sit and watch. Then they will go to the computer room. One person will type, two will sit and watch, where other groups all four people are doing something at...Some people were fearing that with this team work thing, if one person focuses on a particular area they will focus on that area always and the other three won't ever learn that material. I think that's a good thing to think about, but I haven't seen it happening so far. I just had meetings with [the students] yesterday. I had a little 10 to 15 minute meeting with each group and they talked to me about what they were doing and for the most part everyone seemed to know what was going on in their group and how everything was working. Definitely someone knows more about the spreadsheet than others but I don't think that the people that didn't type the spreadsheet are totally oblivious to how a spreadsheet works. If you do something you're going to have a little better knack then the others but I still think they're getting something out of it.

The following comments illustrate the pros and cons of intra-group work. This TA felt that while the group work developed interpersonal and communication skills, it also allowed students to specialize and therefore to miss out on certain aspects of "general education." Several TAs note this advantage of group work.

R: I think because they're so social, often times the students end up talking about social things rather than chemistry. I think because they know each other so well there's often a division of labor such that some people always end up doing certain tasks. Other people always end up doing other tasks, so that there's really no universal learning within the group. It's more of a division of labor, "You do this, don't worry about that, and I'll do that, and I won't worry about this."

I: In the long run, how much detriment will that cause? What do you feel like they may be missing for the future?

R: I'm not sure. I think so much of science and technology is based on personal interactions with people in your research group or your research advisor or people down in sales or the people in marketing, that it's vital that those personal communication skills be developed. So that's one of the big positive ends that I can see of such interactions. At the same time, the division of labor that essentially divides the task so that one student becomes a specialist kind of negates the whole point of a general education, and learning the principles that they'll need for future work.

Another TA expressed similar thoughts.

R: Yeah, that is sometimes a problem. I feel that they are probably not getting as much out of it [group work] as they should be. But, once you [a student] starts working on the spreadsheet, you are the one that understands it best. You are not going to send someone else to work on it that will take them three hours to get the point where they understand it, where they can even do anything on it. So, it is probably the most efficient. But this is learning. I guess it is not supposed to be efficient. It is supposed to maximize your learning.

3.5.2 Inter-group: structured use of First Class Client fostered cooperation

TAs felt that structured use of First Class Client engendered a cross-group communication. One TA recounts the positive effect of using First Class Client. During the first group project, when students were not required to share their insights, the TAs observed limited interaction between groups. However, after Wright required students to exchange ideas over First Class Client, even groups that had been "out of the loop" were benefitting from classwide cooperation.

The following TA quote illustrates the point.

R: I think what helped, and this is true of the second project as opposed to the first. There wasn't a lot of communication between groups. Well, there was for some groups. But other groups were left kind of out of the loop. So some groups picked up ideas from other people and some groups stayed to themselves. And with the second group project, he had them do an initial report that everyone could see on First Class Client. That helped in two ways. It got them actually using First Class Client. And two, the information was there for everyone. So that you couldn't say that these people were hindered because they weren't as social as other groups or they didn't have as many friends in these other sections as this group. So that was a good thing. Whereas before, when you had isolated groups, that was a problem. And they would be a little slower, a little further behind. Some groups found before they even start the experiment they go ask somebody and they would say, "Oh, yeah, "We did the same thing and we had a problem with this and this."

Other TA comments support the importance of learning to communicate skill with other groups of people.

R: I'm not sure. I think so much of science and technology is based on personal interactions with people in your research group or your research advisor or people down in sales, or the people in marketing, that it's vital that those personal communication skills be developed. So that's one of the big positive ends that I can see of such interactions.

Another TA comments:

R: One of the things I think that they had to adjust to was being able to approach problems as a group. One thing we've discovered is that, in looking at the lab projects, when one group gets an idea on how to do something, it just seems to spread through the entire lecture. I think that they have learned to communicate well. Because when you are working on one of these projects you really have no idea what is going on. You go and ask other people what ideas they have. If you hear someone talking about some idea and you are clue-less, you go over and listen and hear what they are up to and word kind of gets around. They really see this course as something that they can overcome. And they are not threatened by the other students, but really see them as resources to help. And they do help each other.

3.6 Value of confrontations/disagreements

Several TAs noted the importance of students learning to manage intra-group confrontations. In the following quote a TA noted that dialogue between students that was forced by disagreement was a productive learning experience.

R: ...One group has two leaders... Well they don't see eye to eye on things but it's working for the group I think: the two argue back and forth on stuff, and it's never heated. It was once and they got through it, but since then the two have been able to argue and work it out. It's helped both of them, I think: through arguing and talking about the science, they've figured out how the science works a little better.

Two other TAs stressed that they allowed the students to work out their disagreements among themselves, as this was "part of the learning experience."

R: Well as far as me helping their adjustments. When the two times I've had a confrontation within group members--in two different groups, there was a confrontation--both of them really didn't receive any help from me. I said, "That is something you have to work out with your group members. You guys have to come to an understanding." And they worked it out. They seemed to work it out. Of course if it ever came to fist-a-cuffs, then the TA would do something. But it wasn't going to be anything like that...They get on each other's nerves sometimes. And that can be really destructive for any given day. And that always happen. There are disagreements and that can slow down the group. A lot of times they can't reach a consensus. There is no clear leadership, in a way, and some groups really need it. So they can get bogged down in discussion and not accomplish anything. When they should be doing some experiments or working on the computer, they're haggling over certain issues that really are irrelevant.

I: *And do you let them haggle?*

R: You bet. It's part of the learning process.

3.7 Dynamics of "bystanders" and "slackers"

TAs observed that certain students acted as "bystanders" or "slackers" within their groups. Bystanders were those people who were slower to "get it" and started developing a dependency on others to provide the answers on homework or projects. Slackers, on the other hand, were those people who were able, but not always willing, to pull their own weight in the group. The following comments represent a TAs' observation of "bystanders" and "slackers."

3.7.1 Bystanders and those who got left behind

R: I like the cooperative learning [method] but the draw back [is that] it does leaves an open space for someone who's not getting it to relax a little too much and say, "I've got three other people that are going to get and if I can't do it myself at least I can go get it from them." And pretty soon it's, "Ah, lets just get it from them." That's the easiest way. Not all people do that. But I can see some people falling into that trap. Of my five groups I think I can only say I really think there's two people in my section that are into that trap. I think everybody else is still pretty conscientious. They're working hard to figure it out.

One TA talked about a student who may have lost motivation towards the end of the semester.

R: There's a few students that have -- I don't know if this was just something about them before they came to class or if it's something that's developed over the semester -- but they've kind of given up. They're still doing the work required to get themselves the B or the AB that they want but the drive that was there to learn has diminished. That's something I've seen in myself and other people as the semester gets later and as you get more tired and worn out, your efforts sometimes tend to wane. But [one student] in particular, has really fallen into the trap of letting the group do the work. [The student is] trying to understand it, but they're having difficulty with it so they just copy the answer and hand it in--

I: That's what we talked about at the formative feedback session.

R: Right and this is brought up with Dr. Wright. In fact he spent two or three hours today with a special session, to try and help this person along and get them caught back up to speed.

3.7.2 Slackers and those who choose not to pull their own weight

This TA comments that slackers are people who have the capabilities necessary to do the work, but who do not pull their own weight.

R: There is the inherent problem that in one group or a couple groups there's the one person who doesn't do anything, and it really can affect the group, especially when there's only four people and one person's not pulling their weight. That leaves three people to do a lot of the work, and they can do it, but there's a sense of that they've been let down, that they have a lot more work to do than the other groups do that have a full complement of personnel actively contributing, so they feel that they're handicapped. And in part they are. So that is one drawback but I don't know how you get around that. I don't think the answer's not going into groups.

This TA went on to say:

R: ...I think for the most part grades are a good indicator of how well you are learning but there are anomalies...

I: Like this one student...

R: Yeah. There's one guy that still getting a B--it's approaching a BC. I think he's learning well but I think he's lazy. I think he just lacks effort. He's not so much worried about getting an A. He knows the stuff and in fact in his group he tends to input some really good ideas. But he doesn't have a real hard drive to make sure he gets every point.

A student may be both a bystander "getting left behind" and a slacker "not pulling their own weight". As observed by the TA, the other members of this student's group have learned to "overcome" this "handicap."

R: I have two groups who have one member in each who don't pull their weight...This other group is a group of four and they have a person who's not working. So they get knocked down to three quite often.

I: Did they come to you about any of this? Is this just your own perception?

R: Oh, yeah. The comments are made, but there's no dealing with the problem here.

I: No one's willing to take on that responsibility that much, to say, "Our group is having a problem."

R: Yeah, that's right. I don't think they really confront her all that much about it. And when she does show up, I think all she does is wash glassware. I think she knows her role or they put her in that role cause they don't want to trust her or count on her cause if she doesn't show up the next lab period...Well, I guess they've worked out a solution where they can now work handicapped, you might say, or disadvantaged. They're doing a fairly good job on this project. They're making progress. So they've probably learned how to overcome -

I: Function.

R: Yeah, just function with her in there. They've learned how to function without her.

3.7.3 Group grading process is sometimes unfair by producing grades that are not commensurate with some individual students' understanding level.

Several TAs felt the group grading process was unfair to students who have bystanders or slackers in their group. In the following quote, the TA discusses the fact that although students generally received full credit on group work, the exams tended to separate the students according to ability. The effect of many students receiving low test grades after building up high grades overall was to create a "morale problems."

R: Yes, I do it as a group quiz because, well that is what was recommended...And it is kind of nice... Well, all of the grades are pretty high then... Maybe out of a ten point quiz, people get 9 or 8 or something. That is always nice for me. I suppose it is nice for the students as well. Although there was an argument for one of the TA's that you don't separate the class according to understanding and ability that way. Because people in a group, if they are not doing well, will tend to do well on all of the group quizzes, all of the take-home exams. All the homework that they work in groups. But then you have to realize that nearly a third of the points are from in-class tests and that, I think, does the separation very nicely. So, that TA was right in one respect, but I don't think that he realized how much worth was put on the individual score. And I think the average was high 50's or low 60's on the last in-class exam. And so even though everyone up to that point had an average of 90 and above, because all the points were available there to get, I think more than other classes, that separated them out. And a lot of students hated that...The effect is, morale problems. Students get really upset. They get upset with the teacher, with the TA's, the class in general. They come in, they don't feel like working. They feel like, what is the point. I've lost all these points and I am going to get a low grade. Why should I even come in here and work. There is no point in it. And uh, it's, it's true, right? They have a good point.

3.7.4 Participation grades not an effective mechanism for enforcing accountability

Many TAs indicated that the participation grades did not have the desired effect of ensuring individual accountability. The students generally did not give poor participation grades when they appeared warranted. Even in cases where students did give low participation scores, the group grade, because it was worth 80% of the project grade, greatly diminished the impact of the participation component.

I: How did the students grade the student who is not contributing? Are they critical?

R: No. Well, yes and no. Some will give 100 to everybody, and maybe it's a little pact, I don't know. I'll give you 100 and you give me 100 kind of thing. Well, it depends. I think if we had another group project they'd be very reflective of individual contributions. The first one, not at all. Everyone got 100, and I know not everyone deserved 100 from each other. In this particular project, they haven't graded each other yet. I have a feeling that it will be a little bit more reflective, but not completely. If they had another project, I think it would be more so then. They would start realizing that we really have to dock this person, make them accountable for their actions, cause that's what it comes down to-- accountability. If you can't count on this person, they should get the grade that they get.

This TA continued:

R: ...At the same time too the students get grades from group projects: 80% of that grade goes to the group as a whole, and then 20% of that grade is an individual grade, that they get to grade each other... If the groups gets a 90, the person who's not pulling their weight gets a 90 [for 80% of their grade]. So now their grade is a score of 90, and the other 20% would be a grade that the students in their group give them. But they pass no matter what and that's probably not fair to the other students. The students were able to make that decision as far as grade distribution, but I have a feeling that they didn't think at the time that there might be problems in the groups, people not pulling their weight. They also didn't want to necessarily--they didn't feel comfortable grading each other. So I think that needs to be explained more. Maybe it was. I don't know to what extent this was discussed by the Board of Governors, and I don't know how they went about discussing it.

Supporting the above TA's comments, another TA talked about the peer pressure on students to give each other perfect scores when not all group members should receive those scores.

R: ...Another problem that I see with this is that, this is another thing that I have thought about and I know that professor Wright has thought about and experimented with, is, how do you proportion grades between the group as a whole and between individuals and their contributions. What we are currently using is a system where, the people in the group grade each other and that is solely what the individual group grade is based on. That and only that. And then the [grade] is assigned to the group as whole. And so they get assigned two grades for each project. And, this is another hard one because it is very difficult as you are going through the lab to really see what individuals are doing and how they are performing. And then the only time that you have to observe them is when they are in lab. A lot of time is spent outside the lab working on the write-up and that sort of thing. And of course, you can't see that. And so, you know because of the difficulties of having a Teaching Assistant assign individual grades. You know that is what Professor Wright has done to this system. But in this system, students feel a great deal of peer pressure and that sort of thing. And so often what happens is that everyone in the group just gives each other perfect scores. If not perfect, at least close to perfect And that has been what has happened with all my groups. And then they can use it as a way to be vindictive as well.

Another TA noted that the grading structure emphasizes accountability in terms of working with the group rather than individual accountability.

R: For the individual student I would say there's not a whole lot of individual accountability. I think there's more accountability in terms of getting with a group, making an effort to try and understand the material in a group, and try and integrate your understanding with the group's understanding. I think after the first midterm, when the results were notoriously low, it was obvious that some aspects of the group dynamics were breaking down...

3.8 Dynamics of leaders and gophers: TAs observe the phenomenon but do not appear to seek to mitigate it.

A few TAs remarked that within certain groups there were those who acted as "leaders" and those who were as "gophers." These TAs did not, however, indicate that they attempted to modify these roles.

R: Yeah, there's definitely leadership dynamics. There's only one leader in one group. That leader stands out brightly [and] the other three are following this leader. The other groups have a tentative leader, [a] person that they seem to go to in times of crisis. But there isn't any inhibition to express your own ideas about what you want to do. There's people that have been affectionately termed "gophers." You'll find the person that always assumes the role to go to the stock room and pick things up...I guess they would be equated with the manual labor type of person. But each group has a leader, however well-defined. It's not, I wouldn't say it's in concrete...

I: ...Sort of an informal relationship?

R: Right. Right. It's not in concrete but there's definitely some kind of structure going on within the group...

4. Academic grading system engenders competition while Wright's course engenders real-life cooperation.

The TAs noted that although the students in Wright's course were graded on an absolute scale, the fact that the larger system of grading on a curve engendered competition and created issues of getting "credit," competition and "credit" remained issues with the students.

In the following quote a TA noted that although students were not overtly competitive with each other, a great concern about grades remained.

> R: I haven't seen any outward signs of competition...I chose to grade the question on the basis of how well you answered the question...The person who explained all the steps in between got full credit and the person who gave a really quick answer got most of the credit but still not all of it. So your thoroughness of the answer was how you were graded. I don't know if this has anything to do with competitiveness but a lot of people, and there's people who got 90s, who were coming in and complaining because they lost a point here or lost a point there. So there are the people that are, are still...
>
> *I: Really worried about every little point.*

TAs commented that competition in Chem 110 was low because of absolute standards (no curve). In the following quote, the TA not only makes this point, but goes on to say that along with the course atmosphere of cooperation, students experienced concern about "getting credit" for their work.

> R: [Competition is] pretty low because of the absolute curve. It is pretty tough not to help out... It makes you feel good if you help out somebody. So, I think that the competition was pretty low. Yeah. The only time, there was one student who had some concern. For the first part of the second project he had a working spreadsheet that worked very well. And everyone asked him how he did it... There are only four groups in my section so I suspect that the other three asked him. And he came up and he said, "How much should I tell them. I worked really hard on that spread-sheet. It took me hours and hours and in five minutes I can save them two hours worth of work. In the final result when Wright reads these, he'll see them with the same results I got and I worked so hard for them. How much should I tell them?" And I said, "Well, that is up to you. It is really none of my business. If you want to tell them, great. If you don't want to tell them, that is your choice." Maybe not the answer I should have given, but... But that's really kind of what it is like out there.

As stated by other TA's in the section under Teaching Goals and Strategies, TA's note that working in groups results in better grades. Thus, the course structure rewarded group work and cooperation.

R: All I can say is that when they work in groups, they tend to do very well. Of course, because they take the best idea of a group, you are going to do better. And when they work individually they get lower grades. And so I suppose from that stand-point they probably would rather work in a group than individually, because they know they get better grades that way.

5. Outcomes

5.1 Effects of difficult open-ended research problems

TAs identified three major outcomes from students' participation in open-ended, group research projects. These outcomes are presented below.

5.1.1 Testing the waters for a "real life" research career

Several TAs reflected on the positive effects of the frustration of working with hard problems. This TA speaks of the group learning experiments as a test of the waters for real life research career, and relates that eventually, after traveling down many "blind alleys," students succeed.

R: Well, I think it's [the lab] been pretty good. For me, I've enjoyed the lab. I think it's done very well. I think it's a good lab for the students and what they are supposed to put together and get from it. And I think that the students actually like it a little more, too, now. I think it's very frustrating because a lot of the work that they do is not standard, cook-book work, especially the last 5 or 6 weeks. They've been doing a lot of independent work. So there's no "look in the book and follow the recipe" that it gives you. So they've hit a lot of dead ends. And they do perform an experiment and it doesn't work out--they get frustrated. "Well, you've got to try it this way now. Attack it from a different angle." They try that. It doesn't work, so it gets very frustrating. . . . But now it's kind of all coming together. Experiments are working. Ideas that they have are starting to work because it's a process of elimination. So now they are feeling pretty good. You know, because they've had some successes. And whether they really like that process or not, in the long run, it's probably very beneficial for them because that's real life. You have a job. You are going to follow a lot of blind alleys, performing experiments. Not everything you try is going to work out. And you have to know that. Whereas a cook-book experiment--it always works out. Right? You always get the answer that you are looking for. That's not what happens in a job. So they are finding out that there are frustrations. Part of any research, there are a lot of frustration, a lot of blind alleys, and a lot of backtracking and trying new ways until something comes up. and it works out. I think they are beginning to realize that.

5.1.2 Learning that understanding the process is more important than a right or wrong answer

Most TAs felt students not only learned real life chemistry and experienced real life problems in research experimentation, but they learned that getting the right answer was less important than understanding the research process and why they reached a particular outcome.

> R: I may be stressing it [the process] more than John, or I may not be, I'm not sure. In this final project they're doing a series of experiments [finding]...hard values related to their particular systems they're working with, and comparing it in part with values that are from other resources, from books, and having them explain why they are the same or different. If the book says the value should be this and you get a value this, why are they different? It doesn't necessarily mean you're wrong, but explain why it could be, why they are different. Also, they have to come up with a theoretical model, or mathematical model, that predicts what they see experimentally, and in part they have to comment on, can they predict it, can they not, what are the reasons why or why not. So there's a process involved here, and they get numbers from the experiment. Whether they're right or wrong, they have a way of judging to some degree how close they are or maybe how far off the book is, et cetera, so there's no absolute right or wrong, you just have to explain differences that they see and how these differences may have come about. Then the model that they have, can they model fairly accurately? If they do, what does that say about your model? What does that say about your data that you've obtained? And if not, what does that say? So the outcome, I'm explaining, the outcome is not right or wrong in my opinion, it's how can you explain the outcome that you ended up with.

5.1.3 Forces development of resourceful experimentation

The TAs indicated that the students had to "try and make sense of everything."

> R: I think the students are learning real life chemistry and experience real life problems in research experimentation...It's real life in that the answers they're getting are not cut and dried. They're not [saying] "Here's my answer, is it right or wrong?" It's more thinking on your feet, it's more digesting and analyzing actual data and trying to make sense of everything...I had friends in engineering disciplines who have gone off to get a job feeling like they know absolutely nothing. And they don't. Because in school they didn't learn any service skills. They've learned how to do certain types of math, certain problems. But all that's done is given the foundation which the company can then work from in order to teach them what needs to be done. And they have to go through incredible amounts of training when they first get their job. And many of them have met, unless they've done an independent research project, they've never gone through this kind of thing, which is when you are trying to make something to work is what you are trying to do.

5.2 Overall Effects

The majority of TA felt that the overall effects of the course were that students experienced higher risks and greater frustration but achieved more benefits and a better understanding of the course concepts.

I: That's interesting. You talk a lot about the frustration, but on the other side, do you feel like students really feel like they're learning, or to what extent do you feel like they a sense of accomplishment, or...?

R: I think when they do accomplish something or when they do get results it is much more personal, and they essentially reap the rewards for their benefit much greater than just turning in a lab sheet and it's like, "It's done, let's move on to the next thing." So I think it might be fair to say the stakes are higher, and if they essentially accomplish the tasks, their rewards and their benefits are greater. If they fail, then because the stakes were so high, there's the additional frustration you get as well.

Another TA said:

R: I guess I have kind of grown to like the idea of having students work in groups. And not that they didn't like it before, but kind of grown to appreciate [group work] because it's just being able to see, I'll have students asking questions like hours and hours, and then someone will ask me a question...and they'll probably get questions answered by one of the other students, "Oh this is how you do it," and goes and answers the question for him, and that's you know it's a good feeling, I can like "Oh gee, what we are doing is actually working here." You know there are students that understand it, not only understand it, understand it well enough to be explain it well to somebody else. And that's a good sign because that's where you really, really can understand it, when it comes to that level.

6. TA Recommendations

6.1 Articulate potential problems with group work early in the semester

Several TAs felt that Wright needed to articulate to students and TAs at beginning typical problems encountered in group work.

R: I think it needs to be brought out more that there will be problems in some groups, and not all groups work effectively, or there will always at least one person in every so many groups that does not pull their weight. How do we deal with them?

6.2 Clarify objectives for group projects

Two TAs mentioned that Wright needed to make a clearer statement of his objectives for the group projects.

> R: The only thing that I could see is perhaps a clearer statement of the objectives of some of the experiments or some of the class projects. Often some of the students will ask me, "Why are we doing this?" A couple times it's come down to, "Let's go check with Doctor Wright and ask exactly what the purpose or what exactly you want in your mathematical model, what he wants you to find with your experiment."

A second TA recommended:

> R: ...[Wright should] be a little more clear about what his requirements and objectives were. Usually what would happen is one of the TAs would see a problem coming up and than they would come ask him about what to do about this problem, and he wouldn't know because he hadn't really thought about yet was the impression ...With a lot of these projects, he has not been very clear and not even the TAs are really clear on just exactly what it is he wants the students to do. I am not sure if he is doing that just because he wants to get some wide latitude to explore things and so he really wants just a hazy goal to give the students something to shoot for. And allow them to use their creativity. Or if he is not really too sure of what he wants himself until. I am not sure. You know I am kind of stuck in the middle because the students are coming and asking me. Well, what is going on. And I have to say "I am not sure." Which is not a very satisfying answer and they are. If they are going to have to work on something they would like to know what their goal is.

6.3 Group students by criteria other than major

A few TAs recommended that students not be broken down by majors, as they were unable to cater to the students interests due to insufficient knowledge of fields that their students had chosen.

> R: ...I think to make such a breakdown [by major] really work or really show benefit is if the TA's were specifically trained in an area and had experience in that area. I think it's kind of unreasonable to divide up the class into medical people and nursing majors, chemical engineers, physicists, chemists, humanities, et cetera and then be able to expect first year graduate students, who are essentially only four years ahead in their training to be able to address specific issues that they themselves had not been trained in. If I were asked to teach the medical section, I have absolutely no background in medical chemistry and the medical sciences. I think those kinds of breakdowns need to occur more on the level of professors rather than one teaching assistants.

6.4 Additional Concerns

Additional problems needing resolution included the lack of lab equipment, and insufficient time for discussion.

I: What have you disliked about lab?

R: Just mainly equipment, lack of equipment, I think.

I: That's still an issue.

R: Yeah, I think in part. At the moment, this late stage, it isn't, but when they first started this last group project, there was still lack of equipment. It is my understanding that this is probably the largest class they've had in awhile, and they haven't had this problem before, so it's somewhat unexpected.

A few TAs felt that additional discussion time might help students, but they doubted whether or not it was feasible..

I: I'm just wondering, there's only one discussion for 50 minutes. Do you feel like there's enough time?

R: No...Usually the bell rings, and someone's in the middle of discussing something, and so we're patient and let them finish. Sometimes it will drag on an extra five minutes because the lecture section follows immediately, so we'll just kind of saunter on down afterwards. Generally things do get rushed at the end of discussion. Well, I think the nature of the material is such that it's difficult inherently, so the more time, the better they'll learn it. Whether another discussion section is justified...or feasible, that's kind of another problem.

Preliminary Quantitative Findings

Students from the two lectures were divided into octiles based on the total points earned in Chemistry 109. The octiles contained approximately 24 students each and were divided into three approximately equal groups, with proportionate representation from the two Chemistry 110 lectures. Each of these groups was interviewed by a faculty assessor from outside the Chemistry Department. Each faculty assessor was provided with brief syllabi of the two lectures and developed his/her own criteria for assessing the competency of the chemistry students. Faculty were unaware of lecture styles and the lecture identity of students. A total of 180 students were assessed (103 from Wright, 77 from Woods).

On the basis of thirty-minute interviews, the faculty ranked the students in their group both relatively and on their own absolute scale.

1. Methods

We adopted three principles in devising our statistical analysis: 1) obtain a simple description of the results; 2) account for both the relative and absolute ranking; and 3) be conservative in interpreting slight differences in relative ranking.

In order to smooth out small differences in ranking, we used the faculty absolute ranking to introduce a derived ranking called the "reduced rank." We use an explicit example to help explain the definition of this derived notion. Here is a possible ranking of eight students (**o** = a Wright student **x** = a Woods student):

o x x x o o o .

The first pair "**o x**" represents the highest ranked two students, but the spacing (the absolute ranking) suggests they are similar in performance. Therefore they would be defined as having reduced rank 1. The next "**x**" is not close to any other "**x**" or "**o**", and therefore it would be the only entry with reduced rank 2. The next "**x o**" are the fourth and fifth ranked students, but again the spacing suggests similar performances. Therefore they would be given reduced rank 3. We could have continued in this fashion, but since there were only 19 students with a reduced rank greater than 3 we defined everyone ***not*** of reduced rank 1 or 2 to have reduced rank 3. In "Table 1, Chem 110 Faculty Assessor Reduced Ranks," below, such a reduction of rank would have been represented as follows:

"reduced rank"
1 2 3
[o,x] [x] [x,o,o,o] .

The brackets are used to group those students with the same reduced rank.

Table 1
Chem 110 Faculty Assessor Reduced Ranks

		Reduced Rank		
Octile	Assessor	1	2	3
1st	1	[x,o,o]	[o]	[x,x]
1st	2	[o,o]	[o,o,o,x,x]	
1st	3	[o]	[o,x]	[o,x,o,x]
2nd	4	[o,o,o]	[o,x]	[x,x]
2nd	5	[x]	[o]	[x,o,o,o]
2nd	6	[o]	[x]	[x,x,o,o]
3rd	7	[o]	[o,o,x]	[x,x]
3rd	8	[o,o,o]	[o]	[o,x,x,x]
3rd	9	[o]	[o]	[x,o,o,o,x,x]
4th	10	[o,x,o,x,o,o,x,o]		
4th	11	[o,o]	[x,x,x]	[o,o]
4th	12	[o,o,o]	[o,x,x]	
5th	13	[x,x,x]	[x,o,o]	[o,o]
5th	14	[o,o]	[x,x]	[x,o,x,o]
5th	15	[o]	[o]	[o,x,x,x,x]
5th	16	[o,x]	[x,x,x,o]	[o]
6th	17	[x,o]	[o,o,x,o,x]	
6th	18	[o,x,o]	[o,x,o]	[x,o]
6th	19	[o,o,x,o]	[x]	[x]
7th	20	[o,o]	[o,o]	[o,x,x,x]
7th	21	[o,o]	[x,o,o]	[x,x]
7th	22	[o,o]	[x,o,o]	[x,x]
8th	23	[x,o]	[x,x,x,x]	
8th	24	[o,o,o,x,o]	[o,o,x,x,o]	[x]
8th	25	[o,o,x]	[o,o]	[o]

Working with this reduced rank the outcomes of the faculty assessment (FA) can be simply represented in a way that satisfies the principles mentioned above. Namely, we cross-classify each student by their 110 lecture and his/her reduced rank. This results in the 2-by-3 "Table 2, Contingency Table," below. A casual perusal of the table indicates a considerable excess of Wright students with reduced rank 1 compared to Woods. In fact, the chi square test strongly rejects the hypothesis that students' reduced ranking is independent of their 110 lecture ($p < .004$).

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Table 2
Contingency Table

	rank=1	rank=2	rank=3	total
Woods	15	29	33	77
Wright	47	33	23	103
total	62	62	56	180=grand total

The analysis below seeks primarily to investigate what additional factors, if any, might explain the difference in the proportion of ranks between the two lectures. A standard statistical approach is to further cross-classify the above **two-way** contingency table by various other factors, resulting in various **three-way** tables (If appropriate even higher **multi-way** tables can be analyzed.) The resulting chi square tests can be used to assess the independence of any combination of factors, or the lack thereof. When two or more factors are found to be **not independent,** one says that there is evidence for a two- or more- way **interaction** between (among) the factors.

B. Results

1. Self-selection effects

a. Self-selection by 109 lecture:
no evidence of interaction (p>.31)

b. Self-selection by octile:
no evidence of interaction (p>.23)

c. Self-selection by gender:
no evidence of interaction (p>.38)

d. Self-selection by 110 lecture and FA rank:
Woods--no evidence of interaction (p>.81)
Wright-no evidence of interaction (p>.17)

2. Gender effects

a. Gender by FA rank by 110 lecture:
no evidence of interaction (p>.85)

3. Grades effects

a. 109 grades by 110 lecture by FA rank:
strong evidence of significant two- and three-way interactions ($p<.05$)

two-way interactions indicated that within each lecture students receiving AB or better were proportinately over-represented among students with reduced rank 1

a three-way interaction indicated that the above two-way effect was stronger in Woods lecture than in Wright's

b. 110 grades by 110 lecture by FA rank:
this was not an informative cross-classification since 144 of the 180 student participants received an A or AB

4. Chem 109 lecture effects

a. 109 lecture by 110 lecture by FA rank:
no three-way interaction was indicated but all two-way interactions were strongly suggested ($p<.05$)

the most interesting obsevation from this cross-classification was that within Wright's lecture there was a proportionate over-representation of students from one of the two 109 lectures amongst the reduced rank 1 students ($p<.09$)

5. Student effects

a. Time-spent out of class by 110 lecture by FA rank:
Students were classified into three groups by out-of-class hours per week spent: low (0-7), mid (8-14), and high (over 15)
[**note**: this information was self-reported by students]

fairly significant two- and three-way interactions were seen ($p<.10$)

a two-way interaction indicated that proportionately more students in Wright's lecture spent over 15 hrs/wk out of class than in Woods' lecture

another curious two-way interaction indicated a proportionate over-representation of students in the low (0-7 hrs/wk) group among students of rank 1.
*[**note**: the largest group was the 8-14 hrs/wk group and the smallest was the 0-7 hrs/wk]*

a three-way interaction indicated that among students in the ***high*** *group (over 15 hrs/wk) a Woods student was much more likely to be ranked 2 than 1 compared to a Wright student*

b. Time-spent with other students by 110 lecture by FA rank:
Students were classified into three groups by the percent time they spent working with other students: low (0-40%), mid (40-60%), high (60-100%)
[**note**:this grouping was based on self-reported information by the students]

this cross-classification indicated that within each lecture time spent with other students was independent of rank (p>.64)

6. Faculty effects

a. Faculty criteria by 110 lecture by FA rank:

This is perhaps the most interesting cross-classification and results are still preliminary.

Based on the faculty assessor surveys and interviews the faculty assessors were divided into four groups which could be said to have **similar criteria** for their faculty assessment rankings. The upshot of this first-pass at accounting for faculty effects is that a good portion of the disparity in ranks between the two lectures was found to lie in the group of students whose assessor was classified as placing a great emphasis on what we termed a student's "meta-awareness" of his/her problem-solving techniques. In fact, among the remaining students (101 out of 180) we find that reduced rank is somewhat independent of 110 lecture within each of the three remaining faculty criteria groupings (p>.19). This is an intriguing observation to which we will devote considerable attention in the future.

Appendix A

This appendix contains the student, teaching assistant, and faculty interview protocols used for the second interviews.

LEAD Center
Assessment and Evaluation of Chemistry 110
Second Student Interview Protocol
Spring 1995

If this is an individual interview, ask the student if he/she will interview with you after exams, and get a phone number where they can be reached. Assure them that we can interview them by phone.

A. Structural Features of the Course

At this point in the course, which part of the course --
- a. lecture
- b. lab
- c. discussion section
- d. homework
- e. out-of-class work other than homework
- f. any other activity

is most important for you in learning chemistry?

How do you feel these different parts of the course "work" together?

Have your feelings about any of these parts of the course changed since we last talked with you?

Has there been any chemistry that you learned in the lab that would have been difficult to understand without the lab?

Were there any topics covered that would have been difficult to grasp without having other people (TAs, lecturer, other students) to talk with?

Would you say that the lecturer follows pretty much the same format every lecture? Could you describe the typical sequence of activities in a lecture?

Would you say that the TA follows basically the same format every discussion? Could you describe the typical sequence of activities in a discussion section?

B. Pleasures and Frustrations with the Course

If you had to name one thing that you really enjoy about this course, what would it be?

If you had to name one thing that really frustrates you about this course, what would it be?

C. Exams and Grading

Describe how you feel about the exams that you've already taken and anticipate taking in this course?

What marks would you give your professor and TA in this course on the way they are grading you? the course overall?

D. Course Impact

Has the course affected the way you think about the "real world"?

Do you think that you will be changed in any significant way by having taken this course?

E. Perception of Others

Since we last talked, have you noticed any new patterns in:

the way you relate to your fellow students?

the way students in the class are treating one another?

How would you describe your working relationship with your TA?

F. Personal Perspectives on Chemistry

Of all the different aspects of chemistry that you were exposed to in this course (e.g., chemical compounds, reactions, atomic structure, etc.), which did you find the most fascinating? Why? How would you find out more about them?

In what ways, if at all, has the understanding of chemistry you developed in this class changed your perceptions of:

a. your day-to-day life
b. industrial society
c. the environment (pollution, agriculture, water quality)
d. nature
e. science

Suppose you were cleaning house and you found a jar with an unknown liquid in it. What would you do with it? Now suppose you put your chemist's hat on and you have access to all the materials and techniques that you learned in this chemistry class. What are some of the properties of the liquid that you might be able to determine?

G. Closure

Are there any other issues or concerns about Chem 110 that you would like to discuss?

Do you have any questions or comments that you would like to share with me?

LEAD Center
Assessment and Evaluation of Chemistry 110
Second TA Interview Protocol
Spring 1995

Introductions
Explain the purpose of the second interview (followup).

Questions

Background:

At this point in time, what are your feelings or thoughts about the preparation you had for being a TA in this course?

Goals:
If you can recall your student learning goals with regard to lab, have those goals changed? If so, why?

a) To what extent have your goals been met? b)In what ways do you know that these goals have been met or not?

Perception of Self:

Has your view of your role as a TA in Chem 110 changed? If so, how did that change come about?

Perceptions of Students and Learning Issues:

Now that the semester is coming to an end, how do you feel your lab has gone?

How has your discussion section gone?

For Wright's TAs:
Apparently all of the lab groups in Wright's sections are organized according to intended major. Which group do you have? What effect if any has this arrangement by major had on the students? (Probe for learning issues, social issues)

Describe the student-student relationships that you observe. Are there aspects of these relationships that you consider positive, and if so, which ones and why? Negative? What effects if any do these relationships have on the students'? (Probe for effects on learning.)

From your perception, what and how much have the students learned this semester in Chem 110?

In our initial interviews with students from both Chem 110 sections, we heard them express that at the beginning of the class, they were adjusting to certain features of the course structure. How well do you feel students have adjusted, and what helped or hindered them in this adjustment?

In your experience, have you noticed any differences in laboratory behavior and/or course performance between men and women?

In your experience, have you noticed any differences in laboratory behavior and/or course performance between students of different ethnic backgrounds?

Teaching:

Since we last talked, has there been any change in the amount of time and the level of responsibility that this class has required of you?

During your first interview we talked extensively about your teaching activities and style. Have there been any changes in your method or any aspect of your teaching? If so, how did these come about?

Are there things that the professor could do to help you as an instructor in Chem 110?

This is a question that we asked last time, but I'm wondering if there has been any change over the semester: Does the professor's teaching style influence the way you teach? If no, why not? If yes, in what way?

Closure:

We will be interviewing students for the second time soon. Do you have issues that you want discussed or specific questions you would like the students to discuss?

Is there anything else that you can tell us in order to understand Chem 110 better?

Do you have any questions for me?

LEAD Center
Assessment and Evaluation of Chemistry 110
Second Faculty Interview Protocol
May 1995

A. Were there any developments or events of particular note that occurred with your Chem 110 class during the last half of the 110 semester? If so, how did you respond to these developments or events.

B. This assessment study intentionally left the criteria by which students were to be evaluated as open as possible, so as to allow each faculty member to draw on the criteria that really are important to him or her. If we agree that "Goals are linked to Strategies are lined to Outcomes (assessments of how well strategies achieved the goals), then the strategy of allowing faculty outside the department to formulate their own assessment criteria to assess student learning also allows them, by implication, to formulate their own goals for student learning.

Were there any surprises for you in terms of the criteria and implicit goals for student learning formulated by the faculty assessors?

C. Were there any other "surprises" for you, as you look back over your experience with this course this semester?

D. The assessment results, while not yet properly analyzed, suggest that there is a "program effect." Optimally, we will be able to say something definitive about factors that are correlated with this effect.

Are there factors you would particularly like us to examine?

E. What, if anything, would you say you learned from having been part of this "Chem 110 experiment"?

F. Will the "Chem 110 experiment" effect the Chemistry Department at large, or in other departments/colleges within the university? If so, in what ways?

H. How could the experiment be improved?
-- study design
-- student evaluation sheets
-- faculty and student survey questionnaires

H. Have the formative feedback sessions the LEAD Center has held proven to be valuable for you? If so, in what ways? Could you describe any effects on you and your course that have resulted from participating in an evaluation process?

F. Do you have any other observations or comments you would like to share with me?

LEAD Center
Assessment and Evaluation of Chemistry 110
Faculty Assessor Interview Protocol
May 1995

Debriefing (if no prior debriefing meeting) and Informed Consent

A. Why did you decide to participate in this study?

B. What, if anything, would you say YOU learned from the opportunity to hold assessment interviews with first-year chemistry students?

C. This assessment study intentionally left the criteria by which students were to be evaluated as open as possible, so as to allow each faculty member to draw on the criteria that really are important to him or her. Sometimes these criteria are quite clear, but often are implicit. As you think back on how you evaluated and ranked your Chem 110 students, how DID you distinguish among them?

> Prompt at end of faculty response:
> What, if any, effect did student's communication skills have on you?

D. Mechanics of the assessment interviews

> How successful were you at helping students feel comfortable?
>
> Were you able to keep within the half-hour time limit?
>
> Did you become aware during any of the exams whether a student was in either Professor Wright or Woods' class?

E. Do you think that participating in this assessment experiment will have any effect on:

> 1. your own teaching?
>
> 2. your relationship to other departments/colleges within the university?

F. Were there any "surprises" for you, as you look back over your experiences preparing for, conducting, and evaluating these student interviews?

G. How could the experiment be improved?
-- preparatory session with Paul Williams
-- study design
-- student evaluation sheets
-- faculty and student survey questionnaires

H. Do you have any other observations or comments you would like to share with me?

Appendix B

This appendix contains the following information about the Chem 110 Faculty Assessment (FA) Project:

- Description of the Faculty Assessment Project
- Listing of faculty assessors
- The information and questionnaire packet for faculty assessors
- Student Survey distributed by the faculty assessors

Description of the Chemistry 110 Faculty Assessment (FA) Project Methodology

To help determine if any differences in learning outcomes for students might be attributed to differences in teaching methods, the following assessment plan was designed by Professor Wright in cooperation with Professor Woods and the LEAD Center.

- *To determine how well Chem 110 is meeting students' needs for competency in a broad range of majors,* faculty from diverse departments outside of the Chemistry Department were asked to serve as faculty assessors (see list in this appendix).

- *To help ensure that differences noted are a function of experimental or comparison course experience rather than students' incoming knowledge/skill levels,* the students from each class were organized into eight "assessment groups" determined by their gradepoint percentile in Chem 109 and formed into octile groupings. Three faculty assessors were assigned to each octile. Students from Wright's and Woods' lectures were assigned to each assessor's group in numbers roughly proportional to their distribution between the lectures (there were more Wright than Woods students).

- *To ensure that the Chem 110 faculty did not impose their criteria for assessing competency on the faculty assessors,* the assessors were given a very generally-stated request: "Assess each student in terms of his/her competence." A pre-assessment preparation meeting, facilitated by a professor not otherwise involved in the experiment (Paul Williams, Plant Pathology), was held in order to answer assessors' questions, advise them on how to put students at ease at the beginning of the exam, and help each begin to formulate his/her *own* oral exam criteria and questions.

- *To lighten the time demands on faculty assessors,* LEAD Center staff made all student-faculty scheduling arrangements. Assessment interviews were half-hour, one-on-one meetings in faculty offices.

- *To ensure each assessor remained uninformed of each student's Chem 110 lecture section,* both professors asked their students not to disclose their lecture section to assessors.

- *To ensure that students would attend the oral exam and to minimize any related anxiety:*

  Professor Wright told his students that they were being asked to participate in these oral exams because oral exams are better than written exams in assessing what students actually know, outside assessors are more impartial, and the point of the assessment is to make a comparison of the teaching methods used by Wright and Woods. His syllabus announced that 25 out of 1000 course points will be determined by this assessment grade.

  Professor Woods told his students that they would be graded on the basis of participating in the assessment exam, and that the assessment would be used to evaluate the course methods that the two professors used.

- *To obtain systematic outcomes data,* each assessor was asked to complete an Oral Examination Preparation Exercise sheet, an Evaluation Sheet on each student, and a Summary Questionnaire (included in this appendix). As part of the Summary Questionnaire, each assessor was asked to present a relative ranking among their students and to indicate the spread in the ranking. In addition, each student was asked to complete a Student Survey (included in this appendix). Among the student survey questions was a request to indicate if the student self-selected into a particular lecture section.

- *To understand the relationship between assessor's rankings and assessment criteria,* each assessor was asked to describe in writing the factors used to assign the rankings, and was interviewed about his/her assessment process by a LEAD Center researcher after all the assessment data had been collected.

- *To inform the faculty assessors about the design and outcomes of the experiment in which they participated,* and to generate cross-departmental dialogue about the experimental course, the LEAD Center held debriefing sessions with the faculty assessors.

LastName	FirstName		Address	Department	Email	Phone	Fax #
Anderson	Marc	ML	Rm 109 Hydraulics Lab	Department of Civil & Env Eng	marc@coefac.engr.wisc.edu	2-2674	
Attie	Alan	B	Rm 210 Biochemistry Bldg	Department of Biochemistry	attie@biochem.wisc.edu	2-1372	3-9609
Babcock	Susan	C	Rm 921 Engineering Research	Materials Science Department	babcock@macc.wisc.edu	3-5696	3-1087
Baumann	Steve	D	Rm 207 Van Vleck Hall	Department of Mathematics	bauman@math.wisc.edu	2-0077	3-8891
Baumgartner	Lukas	ML	Rm 279 Lewis G Weeks Geol Sci	Department of Geology	lukas@geology.wisc.edu	2-8249	
Bertics	Paul	A	Rm 571A Medical Sci Center	Department of Biomolecular Chemistry	pbertics@med.wisc.edu	2-8667	2-5253
Bray	Kevin	B	Rm 4635 Engineering Hall	Department of Chemical Engineering	bray@engr.wisc.edu	2-9053	2-5434
Burnette	Ron	G	Rm 5330 Chamberlin Hall	Department of Pharmacy	burnett@macc.wisc.edu	2-3814	2-3397
Cameron	Doug	F	Rm 3637 Engineering Hall	Department of Chemical Engineering	cameron@engr.wisc.edu	2-8931	2-5434
Certain	Melinda	F	Rm 515 Van Vleck Hall	Department of Mathematics	certain@math.wisc.edu	3-7490	3-8891
Connors	Ken	A	Rm 5328 Chamberlin Hall	Department of Pharmacy		2-2990	2-3397
Denton	Denice	H	Rm 262 Engineering Hall	Department of Elec & Com Engineering	denton@engr.wisc.edu	3-2354	5-2614
DePablo	Juan	E	Rm 3018 Egineering Hall	Department of Chemical Engineering	depablo@engr.wisc.edu	2-7727	
Evenson	Merle	H	Rm 5671 Medical Science Center	Department of Clinical Chemistry	mevenson@macc.wisc.edu	2-1384	3-5738
Hellstrom	Eric	E	Rm 232 Materials Sci & Eng Bldg	Materials Science Department	hellstrom@engr.wisc.edu	3-9462	3-1087
Helmke	Phil	F	Rm 263 Soils	Department of Soil Service	pahelmke@facstaff.wisc.edu	3-4947	5-2595
Hill	Charles	D	Rm 1004 Engineering Hall	Department of Chemical Engineering	hill@engr.wisc.edu	3-4593	2-5434
Kim	Sangtae	G	Rm 3020 Engineering Hall	Department of Chemical Engineering	kim@chewi.che.wisc.edu	2-5921	2-0832
Martin	Tom	C	Rm 5519 Biochemistry Bldg	Department of Biochemistry	tfmartin@macc.wisc.edu	3-2427	2-3453
Matyi	Richard	B	Rm 1327 Engineering Research	Materials Science Department	matyi@engr.wisc.edu	3-1716	2-8353
Millar	Susan	ML	Rm 434 LEAD Center	LEAD Center	smillar@engr.wisc.edu	5-5943	5-5923
Millar	Terry	C	Rm 315 Van Vleck Hall	Department of Mathematics	millar@math.wisc.edu	2-6310	2-5134
Nagel	Alex	G	Rm 803 Van Vleck Hall	Department of Mathematics	nagel@math.wisc.edu	3-3714	5-2275
Nelson	David	F	Rm 156 Biochemistry	Department of Biochemistry	nelson@biochem.wisc.edu	3-6879	3-5137
Pasch	Judith	ML	Rm 414 LEAD Center	LEAD Center	pasch@engr.wisc.edu	5-6369	5-5923
Root	Thatcher	A	Rm 2010 Engineering Hall	Department of Chemical Engineering	thatcher@engr.wisc.edu	2-8999	2-5434
Royer	Cathy	E	Rm 4330 Chamberlin Hall	Department of Pharmacy	royer@macc.wisc.edu	2-7810	2-3397
Valley	John	D	Rm 345 Lewis G Weeks Geol Sci	Department of Geology	valley@geology.wisc.edu	3-5653	2-0693
Williams	Paul	ML	Rm 495 Russell Lab	Department of Plant Pathology	wilpaul@macc.wisc.edu	2-6496	
Zografi	George	H	Rm 5311 Chamberlin Hall	Department of Pharmacy	zografi@macc.wisc.edu	2-2991	

LEAD CENTER
LEARNING THROUGH EVALUATION, ADAPTATION AND DISSEMINATION
UNIVERSITY OF WISCONSIN - MADISON

Chem 110 Teaching Experiment
Materials for Faculty Assessors
April 21, 1995

INFORMATION FOR FACULTY PARTICIPANTS

Thank you for agreeing to participate in this experiment designed to help us better understand relationships between teaching approaches and student learning in chemistry. The attached materials will provide the LEAD Center research data associated with the oral examination element of this experiment.

The attached materials include:

- Information about Faculty-student Interview Schedules
- scratch paper (for use during the meeting with Paul Williams)
- 1 Oral Examination Preparation Exercise sheet (to be completed by faculty)
- 10 Evaluation Sheets (to be completed by faculty)
- 1 Summary Questionnaire (3 sheets, to be completed by faculty)
- 10 Student Surveys (to be **completed by students**)

Participation involves the following steps:

1. (Optional) Attend a meeting facilitated by Paul Williams to discuss the oral exam process with other faculty assessors.

2. Complete the "oral examination preparation exercise" sheet prior to conducting your first student exam.

3. Conduct all the scheduled exams.

    a. Use 30 minutes for each exam. (Please bear in mind that this is a very short time, given the goals of the exam.)

    b. Start each exam by putting the student at ease. This will improve the quality of the results of the experiment. Please explain in your opening remarks that while this *is* an exam, the most important outcome will be information from all the student exams which will be used to help improve science courses at UW-Madison and nationally. This may help the student feel some ownership in the larger process of the experiment. Please also express your appreciation to the student for participating in this experiment on science teaching and learning.

1402 University Avenue, Rm 435, Madison, WI 53706
608 265-5920 • fax: 608 265-5923 • email: lead@engr.wisc.edu

c. At the end of the 30 minutes, give the student one of the enclosed student survey forms. Emphasizing that the **LEAD Center will keep all student survey responses confidential**, ask him/her to take a chair outside your office and complete the survey within 15 minutes (or less). Ask the student to seal the completed survey in the envelope provided and slip it under your door. Place each envelope in the manila envelope attached to this packet.

d. During the 15 minutes the student is completing their survey, complete a "Student Evaluation" on the exam you just conducted. (Please do not put off completing this Student Evaluation, as your immediate impressions will fade rapidly as you see successive students.)

e. (Optional) Take notes on your own thoughts about the evaluation process as you proceed through the exams for use in Step 4.

4. Complete the Summary Questionnaire.

5. Place your oral examination preparation exercise sheet, individual student evaluation sheets, and summary questionnaire sheets into the enclosed large manila envelope along with the student survey envelopes. Arrange for this manila envelope to be hand delivered to the LEAD Center either by having it delivered yourself or by calling Bill Bigler (5-5920). (Hand delivery is strongly preferred because this envelope contains the only copy of data which you will have collected with substantial effort.)

Please ensure that your completed packet is **delivered to the LEAD Center directly after your last oral exam (or by May 15)**. The LEAD Center must provide Professors Woods and Wright copies of the Evaluation Sheets for their use in assigning final Chem 110 grades.

6. Meet with a LEAD Center researcher during the last two weeks of May for a 30- to 45-minute interview. In this interview we will ask you to reflect on your experience with the Chem 110 assessment process. We will contact you to schedule this interview.

If you have questions, you can contact either:

	phone	**email**
Paul Williams	2-6496	wilpaul@macc.wisc.edu
Susan Millar	5-5943	smillar@engr.wisc.edu
Claude Woods	2-2892	woods@bert.chem.wisc.edu
John Wright	2-0351	wright@chem.wisc.edu

Again, we value your participation. We look forward to reporting interesting results from this experiment.

INFORMATION ABOUT FACULTY-STUDENT INTERVIEW SCHEDULES

On April 24 and 25 the LEAD Center is scheduling students into the times faculty indicated were available.

Each student will be given an appointment slip that contains:

- date and time of the exam
- faculty assessor's:
    - name
    - office address (if more than one, the first listed in the Staff Directory)
    - phone number/email address

The appointment slip states that if the student **must** change the appointment, it is his/her responsibility to arrange for the change by contacting the faculty assessor.

The LEAD Center will email your interview schedule as soon as possible, hopefully on April 26. Included with this schedule will be the name, phone number and email address of each student whom you will interview. We ask that if you must change an oral exam appointment, you arrange the change yourself. We believe that this approach will be much more successful than trying to have the LEAD Center reschedule subsets of 26 faculty members' schedules. If you find it is impossible to reschedule a certain appointment, please contact Judy Pasch (5-6369).

ORAL EXAMINATION PREPARATION EXERCISE (to be completed by faculty)

Both in preparation for conducting your Chem 110 oral examinations and to provide the LEAD Center data on the examination process, please respond below to the following request:

> List and describe factors you will look for in your dialogue with each student to assess his/her competence.

Your name______________________________

EVALUATION SHEET (to be completed by faculty)

Date: May ___, 1995

Your name________________________________

Student's name________________________________

This is the (please circle) 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th

student I interviewed.

Please circle a number for each of the following statements:

	Disagree						Agree
1. During the oral exam/interview this student appeared at ease.	1	2	3	4	5	6	
2. This student is well-prepared for introductory courses in science majors.	1	2	3	4	5	6	
3. I am confident that this student's performance on this oral exam reflects his/her true competence.	1	2	3	4	5	6	
4. Taking into account all the criteria formulated in my oral exam preparation exercise, this student demonstrated overall competence.	1	2	3	4	5	6	

Describe below and/or on the back the factors that reflect on this student's overall competence.

SUMMARY QUESTIONNAIRE (to be completed by faculty after all student exams)

A. Now that you have rated each of your Chem 110 students with respect to his/her competence in an oral exam, please take a few minutes to consider all the students you interviewed and rank them relative to one another.

Relative ranks (1 is most competent)

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

Now, using the scale below, please indicate the **spread** in your competency ranking. For example,

a close spread: ¦-----¦-¦-¦¦-¦--¦¦-------------¦
7 6 54 3 21

a wide spread: ¦-¦----¦---¦---¦--¦---¦----¦---¦
7   6   5   4 3   2   1

low high
¦--¦
competence competence

B. Please review your responses to the "preparation exercise" completed prior to conducting these oral exams.

Did you modify your understanding of the term "competency" as you proceeded through the seven interviews? Please explain in the space below.

C. Please comment in the space below on the entire process, including the oral exams, individual ratings, and comparative ranking.

D. In the space below please describe any prior knowledge you had of Professor Wright's and/or Professor Woods' teaching methods/approach.

E. Please describe in the space below your own teaching methods/approach.

Your name______________________________

CHEM 110 STUDENT SURVEY

Instructions: The questions in this survey are intended to help LEAD Center researchers understand your experience in the oral exam and the course overall. All responses to these surveys will be kept confidential. The LEAD Center will report only summary data in which individual students' viewpoints cannot be identified. Please complete the survey during the 15 minutes after your oral exam, place in the attached envelope, seal, and slip under the faculty assessor's door. The faculty member will place your sealed survey, along with those of other Chem 110 students he/she interviews into an envelop for delivery to the LEAD Center.

Your name______________________________

Chem 110 Lecture section (**please circle**): Woods Wright

Name of faculty member who interviewed you______________________________

Using a scale of 1 to 6, where 1 means "disagree" and 6 means "agree," please circle the number which most approximates your view. (**Circle one number**)

	Disagree						**Agree**
Q1. During the oral exam I felt at ease.	1	2	3	4	5	6	
Q2. During this exam I demonstrated what I learned in the course.	1	2	3	4	5	6	
Q3. In the interview I demonstrated the ability to relate my knowledge to new contexts.	1	2	3	4	5	6	
Q4. In the interview I was fluent in responding to the examiner's questions.	1	2	3	4	5	6	
Q5. In the interview I demonstrated that I am knowledgeable of chemistry.	1	2	3	4	5	6	
Q6. I appeared nervous during the interview.	1	2	3	4	5	6	
Q7. I feel well-prepared for other science courses.	1	2	3	4	5	6	
Q8. Comparing what I learned in Chem 110 to other college courses I have taken, I rate Chem 110 at the top.	1	2	3	4	5	6	

Q9. Using a scale of 0 to 100, what grade would you assign yourself, based on the competence you demonstrated in the oral exam? ________

Q10. Describe in the space below the criteria that you believe the professor who conducted the oral exam used to evaluate your performance.

Q11. How many hours per week (on average) did you spend doing out-of-class work for Chem 110? **(CIRCLE ONE NUMBER)**

1. 0 - 3 HOURS
2. 4 - 7 HOURS
3. 8 - 11 HOURS
4. 12 - 14 HOURS
5. 15 - 17 HOURS
6. 18 - 20 HOURS
7. MORE THAN 20 HOURS

Q12. Of the hours I spent doing out-of-class work for Chem 110 (as indicated in Q11), what portion was spent working with other students? **(CIRCLE ONE NUMBER)**

1. 0% - 20%
2. 20% - 40%
3. 40% - 60%
4. 60% - 80%
5. 80% - 100%

Q13. Please comment on your experiences in Chemistry 110, using the lines below.

Q14. When you enrolled in Chem 110, did you intentionally seek to enroll in either Woods' or Wright's lecture section? **(CIRCLE ONE NUMBER)**

1. NO
2. YES If yes, did you get into the section you originally wanted? **(CIRCLE ONE NUMBER)**
   1. NO
   2. YES If yes, please explain on the lines below why you wanted to get into that section.

Thank you very much for your time and attention!